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CONTENTS

	Page
Assessment of the Adaptability of Livestock to Climatic Stress, Douglas H. K. Lee and Ralph W. Phillips	391
Observations on Pigmentation of Eyelids of Hereford Cattle in Relation to Occurrence of Ocular Epitheliomas, H. R. Guilbert, A. Wahid, K. A. Wagnon and P. W. Gregory	426
The Effect of Winter Supplementation on Subsequent Gains of Beef Steers on Grass and in the Fattening Lot, W. E. Connell, S. S. Wheeler and R. C. Tom	430
Value of Distillers Dried Solubles and Distillers Dried Grains with Solubles in the Rations of Dairy Calves, J. R. Schabinger and C. B. Knodt	434
Development of Hyaluronidase in Bull Semen, James E. Johnston and John P. Mixner	440
Comparative Study of Hen Egg Yolk Citrate and Turkey Egg Yolk Citrate Diluter in the Preservation of Bull Spermatozoa, P. T. Basu and R. O. Berry	447
The Effects of Feeding Thyroprotein on Semen Characteristics of Rams, Orson N. Eaton, Ralph G. Schott, Victor L. Simmons and Archie H. Frank	449
Comparison of Corriedale×Navajo and Romney×Navajo Crosses, James O. Grandstaff	455
The Effect of Hemopoietic Dietary Factors on the Resistance of Lambs to Parasitism with the Stomach Worm, Haemonchus Contortus, W. C. Weir, T. L. Bahler, A. L. Pope, P. H. Phillips, C. A. Herrick and G. Bohstedt	466
The Effect of Dietary Fat on Utilization of the Energy and Protein of Rations by Sheep, R. W. Swift, J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek	475
Raising Newborn Pigs to Weaning Age on a Synthetic Diet with Attempt to Produce a Pteroylglutamic Acid Deficiency, B. Connor Johnson, Marian F. James and J. L. Krider	486
Feeding Grains of Different Protein Content, L. W. McElroy, W. Lobay and R. D. Sinclair	494
Crystalline or Crude Concentrates of B-Vitamins Supplement a Corn-Soybean Meal Ration for Weanling Pigs in Drylot, J. L. Krider, D. E. Becker, R. F. Van Poucke and M. F. James	501
The Storage of DDT in the Tissues of Pigs Fed Beef Containing This Compound, R. H. Carter, P. E. Hubanks, H. D. Mann, J. H. Zeller and O. G. Hankins	509
Abstracts of Papers to be Presented at 1948 Annual Meeting of the Society	511
Breeding and Genetics Section	511
Extension Section	517
Meats Section	517
Nutrition Section	520
Pasture and Range Section	535
Physiology Section	538
News and Notes	547
Subject Index	551
Author Index	568

Contents of previous issues of the JOURNAL OF ANIMAL SCIENCE are indexed in the Agricultural Index which is available in most libraries, and in the November issue of each complete volume of the JOURNAL.

ASSESSMENT OF THE ADAPTABILITY OF LIVESTOCK TO CLIMATIC STRESS

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Introduction

ANIMALS are not born equal! In no respect is this more forcibly demonstrated than in the reactions of various animals to climatic stress. Even breeds within the same biological species may show definite and economically important differences under naturally occurring but critical conditions.

While practical experience has resulted in a rough and ready selection of those species, breeds and strains which "do well" in a given environment, the time has long since come when this empirical knowledge needs to be critically examined and supplemented by scientific procedures. This has been the history of progress in every sphere of life; it has been the history of progress in the improvement of plant stocks; it will form the basis for wise development of animal stocks.

The purpose of this paper is to review the present state of physiological knowledge as it bears on the problem of assessing the adaptability of livestock to climatic stress, and to point out the way in which the necessary basic knowledge should be extended in the interests of its answer. Much progress has been made during the last two decades in studies of animal genetics and in the application of new knowledge to livestock improvement. In attempts to improve livestock in their ability to withstand climatic stress, the geneticist and the animal breeder must turn to the physiologist and say in effect, "Tell us what characteristics make for climatic resistance and we will see if they can be bred up." Physiologists, thus appealed to, must confess that this field of their science is in a particularly backward condition.

Three activities, logically successive but in practice capable of much concurrent development, are called for: (a) Codification of existing knowledge; (b) Critical examination of that knowledge and conclusions based thereon; (c) Planned extension and application of our knowledge. Before launching into detailed discussions it would be well, however, to attempt a definition, or at least a delimitation, of the field and to set out an order of procedure

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which will serve, at least as a general guide in a subject which naturally possesses as many ramifications and inter-reactions as the life process itself. Table 1 sets out what appears to be a logical arrangement. Climatic stress results from the operation of five groups of climatic elements (temperature, humidity, air movement, solar radiation, barometric pressure) acting singly or in combination. These operate directly upon the animal as well as indirecty through their effect upon such intermediate factors as vegetations, drinking water, parasites and infectious agents, storms. They may affect one or more of the different physiological systems of the animal and through these have important results upon those animal characteristics which are of economic importance—working ability, meat production, hair and wool production, milk and egg production, and reproduction.

An attempt has been made in this review to set out as simply as possible the ways in which the climatic elements affect the working of the homeothermic animal organism, i.e.. give a brief systematic account of the general physiology involved, since this is fundamental to future scientific progress, and to give a summary of the methods of studying reactions of animals to environmental stresses.

TABLE 1. AN OUTLINE OF THE GENERAL RELATIONSHIP OF CLIMATE TO ANIMAL PRODUCTION

Climatic elements	→ *Intermediate factors*	→ *Animal functions*	→ *Animal use*
Temperature	Vegetation	Thermo-regulatory	Work
Humidity	Drinking water	Respiratory	Meat and packing house byproducts
Air movement	Parasites and infection	Cardio-vascular, including electrolyte and acid-base balance	Wool and hair
Solar radiation,	Mechanical effects of weather	Sweating	Milk and eggs
Direct		Behavior	Breeding
Indirect		Nervous and endocrine	
Altitude		Alimentary,	
		Appetite	
		Food supply	
		Digestion and absorption	
		Metabolic	
		Energy metabolism	
		Growth	
		Tissue distribution	
		Reproductive	
		Behavior	
		Fertility	
		Gestation and parturition	
		Nurture	
		Urinary	

Effect of Climatic Stress upon General Bodily Functions

The Heat Balance

An animal's body temperature at any moment is the net result of two sets of events, heat gains and heat losses, the components of which are given in table 2.

TABLE 2. THE HEAT BALANCE SHEET IN ANIMALS

Heat gains	*Heat losses*
Heat produced at rest	Heat lost to surroundings by,
Heat produced by activity,	Radiation
Exercise	Conduction*
Chemical metabolism	Evaporation*
Heat gained from surroundings by,	
Radiation	
Conduction*	

* Assisted by convection.

The temperature of a cold-blooded animal closely follows that of its environment, and almost the only means the animal has of avoiding the consequences of unfavorable environments is by avoiding those environments. This imposes a severe restriction upon the freedom of its life.

It is an advantage for various reasons to a complex chemical engine like that of the higher animal to have a fairly high temperature, and a nearly constant temperature. In practice this can be achieved in a variable environment only by having an inherently high rate of heat production balanced by a controllable rate of heat loss. In the typical mammal living a free life the rate of heat production is largely determined by the biological needs of the animal—eating, seeking pastures, flight from danger—without regard to the necessity of preserving a heat balance, which function is left to a heat-regulating mechanism controlling the various methods of heat loss from the respiratory tract and skin. Under more extreme conditions some modification may also be made in heat production, but this is generally of smaller magnitude.

For normal health and efficiency the body temperature must be kept within certain limits, which vary slightly from species to species. The further the body temperature is displaced from the "normal" value, the greater in general will be the interference with animal functions, until, if displacement is sufficiently great, breakdown and even death will ensue. The regulation of the heat balance in warm-blooded animals is under the control of a portion of the brain which may be termed, for convenience, the "heat-regulating centre," the operation of which will be discussed later.

The warm-blooded animal may be regarded for basic discussion as having a central core of tissue at uniform "body" temperature (figure 1). Surrounding this is a shell of tissue through which the temperature progressively falls as the surface is approached and through which heat flows to the surface by conduction and by convection through the blood stream.

From the surface of the animal heat is exchanged with the environment by radiation and conduction, i.e., heat flows by these physical processes in

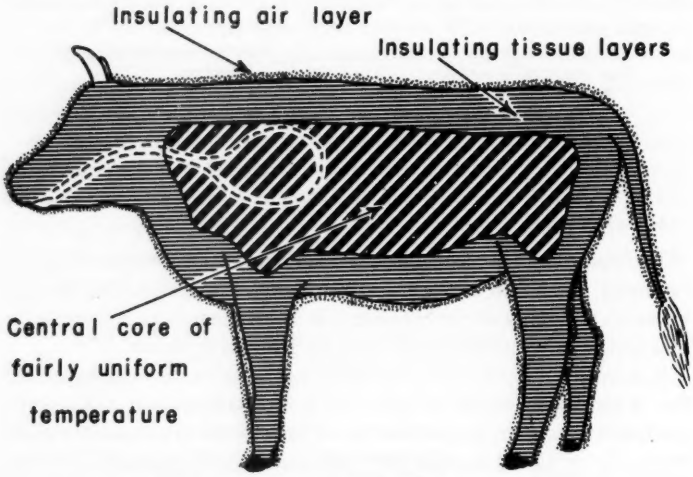

Figure 1. Temperature distribution in an animal.

whichever direction the difference in temperature lies and according to simple physical laws. Heat is also lost from the surface by evaporation of water transuded through the skin (true insensible perspiration), sweat, or water acquired by licking, wallowing or other special means.

Immediately surrounding the animal is a layer of air through which the temperature progressively changes until it reaches that of the ambient air and by which heat flows by conduction and by convection provided through air movement. The effective thickness of this layer is determined by the rate of air movement over the surface.

The respiratory tract may be looked upon as a special part of the body surface with which the air exchanges heat by conduction and from which heat is lost by evaporation of body water.

Without going into the complicated mathematics of the situation, it is important for subsequent considerations to appreciate that the following bodily factors must influence heat loss (see figure 2):

(a) Physical nature of the more superficial tissues, especially their fat and water content;
(b) Blood flow through the more superficial tissues;
(c) Area of body surface;
(d) Color of body surface;
(e) Transudation of water to the body surface;
(f) Sweat production and nature of its distribution on the body surface;
(g) Nature of body surface as it affects air flow over it, especially thickness and density of hair or wool covering, and its contours;
(h) Movements of the body surface;
(i) Coverings applied to the body surface;
(j) Volume of respiratory ventilation per minute.

The Climatic Elements

Temperature. The temperature of the air (and other objects, to the extent that they are in contact with the skin) affects heat exchange by conduction. It is usually expressed in °F. or °C.

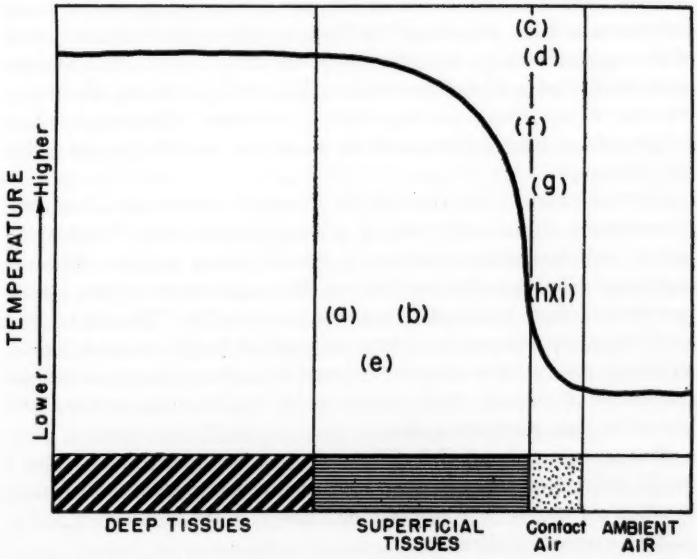

Figure 2. Temperature gradients from the interior of an animal to the atmosphere. Shading indicates corresponding regions of figure 1. Letters in brackets indicate governing body factors listed in text.

Humidity. The absolute humidity of the air affects heat loss by vaporization from the skin (to the extent that water is available for evaporation) and from the respiratory tract. Evaporation is governed by the temperature of the water being evaporated and the relative humidity of the air at that temperature; but the temperature is that of the body surface (which is relatively constant), and not that of the ambient air which is much more variable. Hence absolute, rather than relative humidity, is the measure to use when considering effects upon heat loss by evaporation from a homeotherm. It is usually expressed as grains of moisture per cubic foot of dry air (grs./cu. ft.), or grams per litre; but the vapor pressure (in mm. of mercury) is frequently used instead. (At 96° F., 1 mm. mercury vapor pressure = 0.413 grs./cu. ft.).

Air movement. Air movement affects heat exchange by conduction with and heat loss by evaporation from the body surface, but has little effect upon heat exchange in the respiratory tract. It is movement in all directions and not merely linear air movement which counts, so that appropriate instruments have to be used for its measurement. It is usually expressed as feet per minute or centimeters per second.

Radiation. Surrounding objects not in contact with the animal body will exchange heat by radiation with it. The rate of exchange depends upon the temperatures of the objects and the body surface respectively, the nature of the opposed surfaces, the reflective power of the body surface, and the geometrical relationships of the objects and the body. In the case of sunlight, the color of the surface is also important. It is the most difficult mode of heat exchange to consider mathematically or to measure, but this does not reduce its importance.

Thermal elements. The four climatic elements—temperature, humidity, air movement, radiant heat—may be grouped together as the "thermal elements" and their effects considered conjointly insofar as these effects are dependent solely upon the heat balance. Each may, however, have specific non-thermal effects which call for separate consideration. Thus, for example a high humidity may produce a wet coat in which fungal and other growth may occur and excessive movement of very dry air may damage the delicate conjunctiva of the eye, while certain wave lengths of sunlight are well known for their sun-burning effect.

Barometric pressure. A fifth climatic element, barometric pressure, has a totally different effect upon animal functions, in that it governs the tension at which the necessary oxygen is made available in the lung alveoli, and so calls for separate consideration.

The remaining portions of this section will be devoted to a consideration of the reactions of the warm-blooded animal body to climatic stress in which the following aspects will be considered in turn: Immediate reactions to the direct operation of thermal stress which are of a compensatory nature, tend-

ing to prevent displacement of thermal equilibrium; Immediate reactions to the direct operation of thermal stress which are not themselves compensatory, but are brought about as secondary consequences of heat regulation; Results of the displacement of thermal equilibrium; Immediate reactions to reduced barometric pressure; Reactions resulting from the indirect operation of climate or through modifying factors; Processes of acclimatization.

It will conclude with a list of those bodily characteristics which are likely to influence the operation of climatic stresses, and a summary of the nature and direction of their probable influence.

Immediate Compensatory Reactions to Thermal Stress

It is clearly established that there are groups of nerve cells in the hypothalamic portion of the fore-brain which collectively deserve the name of "heat regulating centre," since they exercise a marked and deliberate control over various physiological processes which affect heat loss from the animal body (e.g., respiratory activity, cutaneous blood flow, sweating). There is some evidence that they also exercise a control over at least some methods of heat production, such as shivering. These centers are extremely sensitive to changes in the temperature of the blood passing through them and it is probable that they are also affected by nervous impulses coming up from nerve endings at or near the surface of the body which are sensitive to temperature change.

When some change is made in the rate of heat loss from the animal, through alteration in one or more of the thermal climatic elements, the temperature of the body surface, of its nerve endings and of the blood flowing through it is correspondingly altered. It is still uncertain how much of the stimulation of the heat regulating centres is mediated through the blood stream and how much through the sensory nerves, but the result is much the same. According to the degree and direction of the stimulation, nervous impulses are sent down from the heat-regulating centres to the appropriate mechanisms through which the heat loss is readjusted to its former value. The exact mechanism used varies greatly with the species of animal and also with circumstances. Table 3 sets out those most commonly used.

The extent to which such apparently compensatory reactions as increased appetite in cold, and decreased appetite and relaxed posture in heat are to be regarded as primary reactions under the direct control of the heat-regulating centers, or as secondary consequences, is debatable. They will be treated as coming into the latter category in this review.

Some lower nervous reflexes also assist in the process of heat regulation, but their activities are generally subject to integration by the hypothalamic centers.

TABLE 3. METHODS OF ADJUSTING HEAT LOSS

Adjusting to cold	*Adjusting to heat*
Constriction of superficial blood vessels	Dilatation of superficial blood vessels
Removal of water from circulating blood	Addition of water to circulating blood
Erection of hairs	Increased respiratory activity
Increased muscle tone and shivering	Sweating

Immediate Secondary Reactions to Thermal Stress

In such a complicated and delicately balanced organism as a homeotherm, it is practically impossible to place a stress upon one function without consequentially affecting many other functions. This is very well exemplified by reactions to thermal stress, as will be seen by examining the major physiological systems in turn.

Cardio-vascular system. In a closed circuit, such as is provided by the heart and blood vessels, mechanical adequacy demands that (1) there is sufficient liquid to fill the system completely; (2) the pump is maintaining an adequate output. The first of these provisions involves two things—the volumetric capacity of the circulation and the volume of blood available for it.

Under cold conditions the capacity of the circulation tends to be decreased by cutaneous vaso-constriction, and there are no particular demands upon the body for water to threaten the blood volume. The volume/capacity ratio tends to rise above unity and the body finds little trouble in getting rid of the threatened excess of water into tissue stores or through the kidneys.

Under hot conditions, however, the reverse is the case. Cutaneous vasodilatation may greatly increase the capacity of the circulation; liquid tends to pass more easily from the blood into the tissues through dilated capillaries, especially in dependent parts; some water is lost by evaporation from the respiratory tract and also from the skin in sweating animals. Constriction of visceral blood vessels may effect some compensation, but at the expense of the visceral functions. For moderate stress, the water stores, together with reduced urine volume, can effect compensation, but this is limited, so that the increase in blood volume required to match the increased capacity may not be realized. Any fall in the volume capacity ratio below unity must lead to insufficient blood supply, and this will be most evident in the top part of the body; while the tissues most sensitive to lack of oxygen will

show the greatest effect. In some animals the brain tissues qualify on both counts.

The heart rate is subject to many influences. The temperature of the blood has a direct effect upon the "pace-maker" in the heart itself, which is slowed by cold, accelerated by heat. The cardio-motor centres in the hind-brain, which control the heart rate, are affected in the same way. The heat-regulating centres may further enhance these effects. It must be realized, however, that deductions as to the cardiac output or general circulatory activity cannot easily be drawn from the heart rate. While in general an increased heart rate goes with an increased cardiac output, this need not be so. The rate may be doubled without any increase in output if there is no increase in the speed with which blood is being returned to the heart through the great veins for output. In general, we may regard a slowing of the heart rate with cold as indicating a decreased cardiac output, but an increase with heat as indicating an increased output only so long as there is a fully adequate venous return. Above this point an increase in rate is a noble but largely futile gesture.

Alimentary system. Any diversion of blood from the viscera to the periphery must constitute at least a potential threat to alimentary function. It is characteristic of mild degrees of oxygen lack that motor functions should be affected more than secretory and it is largely with motor function that appetite is associated. Loss of appetite (anorexia) is commonly associated with heat, in which the visceral may be reinforced by cerebral effects. Other alimentary functions appear to be little affected by heat, except perhaps for a lowered resistance to bacterial infection.

Under cold conditions the appetite is stimulated. The mechanism for this is not clear, but it may well be the result of stimulation to the adrenal medulla from the hypothalamus, if not from the heat-regulating centres themselves. Adrenalin is known to increase hunger contractions under certain conditions.

Urinary system. The chief effect of cold is to increase the urinary volume. This may result partly from the increase in blood flow through the kidneys following peripheral vaso-constriction, partly from changes in the operation of the anti-diuretic hormone of the posterior pituitary gland and possibly from the increased water content of the blood stream. The water represents that not now being evaporated for heat-regulating purposes, together (as an acute effect) with that withdrawn from the blood as a result of cold.

Under hot conditions the urine volume is reduced by the reverse effects, in sweating animals sometimes even to remarkably low figures. Complete suppression never results in the healthy kidney, however, as a minimum volume is maintained for the excretion of soluble waste products. These low

volumes may predispose to the formation of urinary calculi, but heat otherwise appears not to affect renal efficiency.

In animals which lose a lot of chloride in the sweat, some conservation of chloride may be effected in the urine at a time before any significant fall is seen in the blood.

Acid-base balance. Where a marked increase of respiratory activity occurs in response to heat, there is a danger that excessive amounts of CO_2 will be washed out of the blood with a consequent alkalosis or even alkalaemia. In many cases, as the rate of respiration is increased the depth of respiration is decreased, so that this tendency is reduced. Nevertheless it does at times reach significant proportions. In the course of a few hours the renal system will make some adjustment, but in herbivorous animals, which usually have an alkaline urine to start with, this additional excretion of alkali might be expected to favor the formation of urinary calculi.

Nervous system. In addition to its primary participation in heat regulation, the nervous system is secondarily involved in many ways. Reference has already been made to the possible reduction, in hot conditions, of blood supply to the top parts of the body and the sensitivity of the nervous tissue (especially of the cerebral cortex) to lack of oxygen. Any disturbance in acid-base balance might be expected to influence cerebral functions. The nervous impulses set up by alterations in the temperature of the body surface are not dissipated solely over automatic pathways; some enter consciousness and contribute to sensations of comfort. Although the sensation of comfort is often assumed to be a human prerogative, and there is undoubted danger in reading human emotions into animal behaviour, it would be wise to allow some weight to equivalent sensations in quadrupeds, even if the responses are at a thalamic rather than at a cortical level. Most experimenters come to give credence to the importance of "temperament" in the reactions of individual animals.

Endocrine system. There is a good deal of evidence to suggest that the anterior pituitary, the adrenal medulla, the thyroid and the adrenal cortex are involved in reactions to thermal stress, but the mechanisms and exact inter-relationships are still obscure. The probable chief responses are set out in table 4.

There has been speculation on the effect of climate upon the endocrine secretions of the gonads, but the recent demonstration that the seasonal variation in reproductive function can be influenced by the thyroid has transferred attention thither.

Energy metabolism. It has been clearly shown that for the typical homeotherm there is a "zone of neutrality," a range of environmental temperatures over which the resting organism maintains a constant rate of energy metab-

TABLE 4. PROBABLE CHIEF ENDOCRINE RESPONSES TO THERMAL STRESS

Gland	Response to cold	Response to heat
Anterior Pituitary	Increased thyrotropic hormone	Decreased thyrotropic hormone. (?)
Thyroid	Increased thyroxin	Decreased thyroxin (?)
Adrenal Medulla	Increased adrenalin	No change unless there is undue stress, when adrenalin may be increased.
Adrenal Cortex	Increased 17 ketosteroids (?)	(?)

olism (see figure 3). As the environmental temperature falls below the lower limit, the metabolic rate steadily rises, mainly as a result of shivering. This process has limits which will be noticed later in connection with displacement of thermal equilibrium. Above the upper end of the zone of neutrality there is, however, no immediate compensation available, and the behavior of the metabolic rate must again be left to the discussion on displacement of thermal equilibrium. The possibility of a long-term adjustment to heat will be considered under "acclimatization."

When work is being performed, the critical temperature limits of the neutrality zone are displaced downwards to a degree dependent upon the degree of activity.

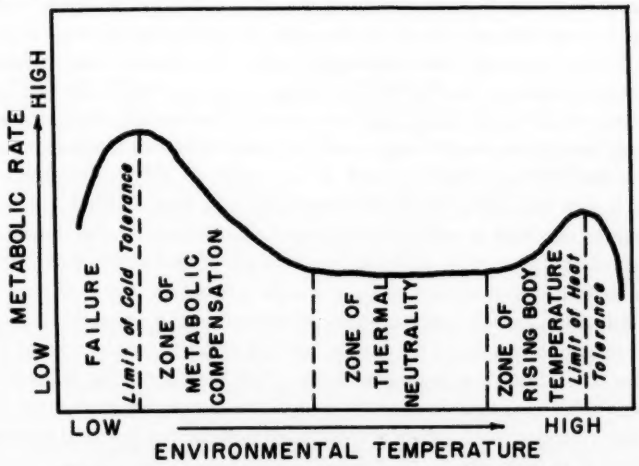

Figure 3. Relationship of metabolic rate in resting animal to environmental temperature.

Reproductive system. Under sub-arctic conditions, the breeding season of animals is usually very restricted. It has been known for a long time that in regions with high summer temperatures fertility is reduced in the summer months. It has been shown that certain desirable semen characteristics, such as high motility and low percentage of abnormal forms, are apt to fall off in the summer months. Little seems to be known of the direct effects of season upon the female reproductive organs. While alterations in the endocrine secretions of the gonads or at least of the anterior pituitary hormones controlling the gonads were naturally suspected, as well as direct effect of temperature upon the testes, attention has recently been focussed on the thyroid gland by the demonstration in some mammals at least that seasonal variations in its activity correspond with variations in fertility and semen characters, and that the seasonal effect can be controverted by artificially administering thyroid hormone in summer or one of the depressant thiouracil drugs in winter. A similar relationship probably exists between thyroid activity and the moult with its reduced laying in domestic birds.

Growth. The temperature at which developing tissues are maintained has a marked effect upon the rate of development, as may be expected. Thus homeotherm young develop much more rapidly than those of poikilotherms, and chicken embryos incubated at 40° C. show increased weight over those incubated at 35° C. It is probable that temperature can be shown to have an influence upon the growth, as judged by body weight, of homeothermic animals during the poikilothermic post-natal phase which many of them possess. It is far from clear, however, what effect may be exerted upon actually homeothermic young by variations in environmental temperature insufficient to change the body temperature. Experimental studies under controlled conditions are few and field observations are complicated by various indirect effects of climate, such as nutrition. Theoretically, the thin rangy animal should have an advantage under hot conditions over the more rotund individual, and vice-versa, in cold. It is possible to point to instances in which such teleological predictions appear to have been fulfilled, but such instances may just as well be coincidental. Sundstroem (1930), however, demonstrated an increase in size of ears, tails and scrotal skin in mice reared in a hot humid environment, in spite of some retardation of general growth.

Coat thickness and hair characters in mammals and plumage in birds are well-known to be affected by climate, but it is not clear to what extent this is due to vascular or to endocrine factors. Nor has the relative importance in this of heat and light been established. There is a possibility that the size of sweat glands as well as their activity may be affected by repeated exposure to heat at an early age.

Results of Displacement of Thermal Equilibrium

Even under stable atmospheric conditions the body temperature varies with the time of day, season of the year, nutritional plane and activity over a range which must be regarded as "normal." If, under climatic stress, it is displaced beyond this range, then function is likely to be impaired in increasing proportion to the degree of displacement, until a critical point is reached beyond which death will result if relief is not quickly afforded. The body temperatures which mark the change from one zone to the next vary considerably with different animals and sometimes with organs in the same animal.

The exact pattern of results varies with the animal, but the major items are set out in table 5 in more or less progressive order.

Up to a certain point, these reactions are reversible with ease; beyond that point the breakdown of the heat-regulating mechanism makes reversal much more difficult. Death of the animal depends, not only upon the body temperature, but also upon the length of time that temperature is maintained. An extreme body temperature may be tolerated for a few minutes, if rapid reversal is obtained, whereas a less extreme temperature maintained for a longer period of time may be fatal. Delayed deaths sometimes occur in the twenty-four hours following exposure, even though the temperature has been brought back to presumably safe levels, but the reason for this is not clear.

TABLE 5. RESULTS OF DISPLACED BODY TEMPERATURES

Results in cold	*Results in heat*
Increased shivering	Agitation
Huddling	Complete anorexia
Decreased activity	Diarrhea
Slow cerebration	Failure of heat regulation with gasping and cessation of sweating
Depressed metabolism	Weakness and stupor
Depressed respiration and heart rate	"Staggers"
Failure of heat regulation with cessation of shivering	Convulsions
Respiratory failure or cardiac failure	

Local effects of cold may be of importance. These are seen particularly in the limbs, since the temperature of the limb usually falls progressively as the distance from the trunk is increased. Freezing of the tissues is usually followed by leakage of fluid from the capillaries into the tissues, clotting of blood in the capillaries and death of the tissues; leading to swelling (edema), pain and gangrene.

Reactions to Reduced Barometric Pressure.

In this air age, the reduction of air pressure with altitude is a matter of commonplace knowledge, as are the effects of such a reduction upon men seeking to operate at those altitudes. The effect is, of course, not a direct mechanical result of pressure, but a chemical one resulting from an inadequate supply of the oxygen necessary for the metabolism of the active bodily tissues. Oxygen constitutes 21 percent of the atmosphere by volume, so that the pressure of oxygen is roughly one-fifth of the total atmospheric or barometric pressure. At the normal value of 150 mm. mercury pressure, oxygen diffuses across the lung membranes to the blood flowing through the lungs at a rate sufficient to meet all normal needs. As this pressure is reduced the rate of transfer decreases proportionately, and the body's ability to carry out high rates of activity involving high rates of oxygen consumption is reduced. Finally, a level is reached at which the rate of oxygen transfer to the blood is insufficient to meet the needs of even the sedentary man. The body first responds by increasing the volume of air respired per minute, by more rapid and deeper respirations, but this protective device has obvious limitations.

When the maintenance of an adequate oxygen supply is beyond the ability of even a rapidly breathing animal, bodily functions must suffer. As in the case of heat exhaustion, the tissue to make its lack most acutely felt is that of the brain. Lassitude, loss of interest, visual disturbance, headache may all be experienced by man, together with a peculiar and characteristic phenomenon which medical men call "euphoria." This last is an exaggerated sense of well-being, a feeling that all is not only well, but better than usual, when, in cold fact, the situation is highly dangerous. It may be likened to a drunken confidence. Under such circumstances highly dangerous errors of judgment may occur, and without any warning.

With very rapid reductions of pressure, such as occur in flying, these effects of oxygen lack (anoxia) may occur uncomplicated, but in the more gradual ascents characteristic of surface transport, another disturbance is likely to develop, at least in man, before the anoxia gets to really dangerous levels, just as heat exhaustion in man usually occurs before his temperature rises to the dangerous levels which bring on heat stroke. This is the condition of "mountain sickness," in which nausea, vomiting and dizziness may reach distressing proportions, and is due to an alkalosis brought on by the "washing-out" of carbon dioxide from the blood through excessive breathing.

It is probable that the counter-part of these phenomena, so distressing to man, will occur in many animals moved to situations in which atmospheric

pressure falls to markedly lower levels. Interference with behavior and judgment might lead to accidents and interrupt normal activities. The working capacity of such animals will almost certainly suffer markedly. It is important, therefore, to know the rate of drop in pressure with altitude, the relative importance of a given drop for different animals, and what might be expected from processes of acclimatization.

On the first point we have fairly exact information. For the first few thousand feet above sea level, the atmospheric pressure decreases at the rate of approximately 25 mm. per 1,000 feet. The rate of decrease of oxygen pressure will be about one fifth of this. At 18,000 feet, the pressure is reduced to about one half. On the second point much more work needs to be done. For man, 10,000 feet is taken as the really safe limit for more or less indefinite occupation, although he can stand higher altitudes for short periods. Pigeons are peculiarly resistant to this type of anoxia, but the exact mechanism for this resistance is not known. Typically lowland animals, such as the sheep and rabbit, show about the same resistance as man, but animals which inhabit high altitudes in their natural state, such as the llama and vicuña, have much higher tolerances. Thus the llama is used as a pack animal up to 17,500 feet, and vicuñas have been chased in an automobile at 30 miles per hour at an altitude of 15,000 feet.

By due processes of acclimatization, many lowland animals can acquire a considerable tolerance to low atmospheric pressures, but the mechanisms employed differ somewhat from those responsible for the tolerance of native animals. A theoretical consideration of the problem would suggest that increased tolerance might be achieved in a number of ways: Increased permeation of the lung membranes; Increased affinity of the blood for oxygen at lower pressures; Increased carrying capacity of the blood for oxygen as by an increased concentration of red blood cells; Increased facility on the part of active tissues to utilize oxygen at low pressures; Increased tolerance on the part of sensitive tissues to low oxygen pressures; Increased tolerance to or compensation for the alkalosis induced by rapid respiration. From the relatively small amount of study that has been devoted to this subject it would appear that typically lowland animals, such as man, the sheep and the rabbit rely largely upon an increase in the concentration of red blood cells, though this may be backed up by improved ability of the tissues to work at low oxygen tensions, or even some compensation for alkalosis. In these animals, there seems to be little support for the theory that the affinity of the blood hemoglobin for oxygen is increased. In the llama, vicuña and Bolivian goose, on the other hand, all native to high altitudes, high values are found for both the concentration of red blood cells and the affinity of their hemoglobin for

oxygen. That these characteristics have been fixed genetically is indicated by the fact that they are retained by first generation llamas born at sea level. In two other high altitude animals, however, the South American ostrich and the rodent viscacha, the red cell concentration appears to be similar to that found in sea-level relatives, but the affinity of their hemoglobin for oxygen is much higher.

Keys (1936) has listed the following apparent limiting altitudes which are of interest in connection with the effects of barometric pressure: Cultivated land in Tibet—15,200 feet; Permanent settlement of 150 people, 'Quilcha, Andes—17,500 feet; Temporary settlement, Andes, abandoned—18,500 feet; Mules ridden, Andes—18,800 feet; Daily work, mining in Andes—19,000 feet; Lichens grow in Andes—20,000 feet; Birds in Himalayas—26,000 feet; Mountain climbing on Mt. Everest—28,000 feet.

Indirect Operations of Climate and Modifying Factors

Food and water. The overwhelming influence of climatic elements upon the supply of food and water needs no emphasis. At times they reinforce the direct effect of climate on the animal, as when the dearth of these necessities in hot dry seasons inhibits reproductive activity; at times they operate contrariwise, as when cold increases the metabolic rate but the destruction or covering of herbage reduces food supply. It is often important to ascertain whether the direct or the indirect effect of climate is the more important, if deliberate action to counter one of them is being considered. It would be a waste of effort to administer thyroxin to rams, for instance, to counteract summer sterility if the food restrictions themselves were such as to inhibit reproduction.

In table 6 are set out the effects of food and water deficiency upon the more important physiological functions, with an indication of how such deficiencies may affect the thermal strain.

TABLE 6. EFFECT OF FOOD AND WATER DEFICIENCY AND ITS RELATION TO THERMAL EFFECTS

Function	Deficiency effect	Relation to cold effect	Relation to heat effect
Cardio-vascular efficiency	Reduced reserve		++
Heat production	Reduced	++*	−
Work	Reduced	·	+
Mating	Reduced	+	+
Urine formation	Reduced	·	++
Coat development	Poor	+	−
Milk and egg production	Reduced	·	++

* + Indicates that the effect upon the well-being of the animal brought about by the direct operation of climate would be aggravated by food and water deficiency.

The plane of nutrition has a marked influence upon animal reactions to heat. Those allowed to eat as much as they wish of a well-balanced ration show definitely greater rises of body temperature, respiratory rate and evaporative water loss than similar animals given only maintenance quantities of the same ration. This is not entirely due to differences in body form brought about by feeding, since the relative sensitivity to heat is reversed more rapidly than body form when the rations are reversed. The percentage of protein in an iso-caloric diet, however, has no such effect upon reactions to even critical conditions of heat.

Parasites and infections. Through temperature, water and herbage, hot humid climates provide a fertile breeding ground for a vast array of parasites and disease vectors, which frequently serve as the most effective bar to animal production. By engineering, by insecticides and by developing immunities, however, they are being brought under control, so that here again it is important to separate the direct effect of climate *per se* upon the animal from those of associated pests, if an estimate is to be made of future possibilities and plans are to be wisely laid. The necessity for such an attitude as regards man himself is already quite clear; its general acceptance in the animal field should not be delayed.

In hot dry climates, the incidence of parasites is much less, but arthropod vectors may still have an important influence, while blood-sucking insects, combined with poor nutrition, will enhance any thermal strain.

Cold climates predispose many animals to respiratory infections, especially if the climate is changeable. Sub-arctic climates, on the other hand, may minimize or even abolish the infective agents.

Mechanical effects. The mechanical effect of wind-driven dust on eyes, respiratory tract, alimentary canal or even hide may at times amount to a hazard of economic proportions. The burning effect of hot sand or rock, the cutting of stones, the smoothness of ice or polished rock and the softness of snow may well present a severe limitation to animals whose feet are not well adapted to the situation. Driving rain may, through its mechanical discomfort, force certain animals to move in dangerous country. Animals that naturally move with a driving snowstorm may sustain physical damage and even death by "piling up" against a fence or other obstruction.

Activity. Activity increases heat production, increasing the thermal stress in hot conditions, relieving it in cold. Limiting conditions are thus varied by the degree of activity required of the animal. Training to exercise under conditions likely to be encountered is an important factor in determining an individual animal's reaction. An animal turned out to pasture has to be reconditioned, but one fed and exercised retains its training.

Sunburn. That part of solar radiation which has short wave-lengths ("ultra-violet") contributes little to the total heat load but has important

properties in that, after absorption by tissues, it causes damage to their cells. This damage is recognized as sunburn on the skin, or as one type of conjunctivitis in the eye. For its occurrence a certain intensity and a certain total dose of radiation of the appropriate wave lengths must be absorbed by sensitive tissues. Dust content of air, water content of air, heavy cloud, dense coat, deeply pigmented coat, thick epidermis, and deeply pigmented epidermis all tend to reduce the damage below the critical level, or even to abolish it. Alternation of the part exposed also reduces its incidence. It is important to remember that these short wave lengths may be reflected to an important degree from snow, light cloud or still water. Their reflection from white sand is less but may be significant.

Light. It has long been recognized that light exercises important effects upon the physiological activities of many birds, and impressions that the same is true for some mammals have recently received experimental confirmation. The effects are particularly noticeable upon reproductive functions and upon the plumage of birds and the coat of mammals. The exact mechanism by which light invokes these reactions is still being investigated, but present suggestions are that certain skin areas of the face region, and perhaps the eyes, give rise to nervous responses which influence the anterior pituitary and thus the general endocrine balance controlling metabolism, reproduction and coat characters. It is clearly difficult to disentangle under naturally occurring conditions the effects of light *per se* from those of the heat elements in climate, but some progress is being made in this direction.

Acclimatization

When an animal is exposed continuously or repeatedly to a hot environment two time processes are involved, one (acclimatization) tending to diminish the animal's departure from normality and the other (deterioration) having a cumulative effect tending to increase the reaction. Which gains the ascendancy depends upon the species, the individual animal, the severity of heating and probably upon a number of other ill-recognized factors. With cold, on the other hand, evidence of either process as a universal phenomenon appears to be less certain. While early experiments were done with animals, recent work has been almost entirely upon man. This needs checking and supplementing by careful animal investigations.

The resistance of an animal to thermal stress could be altered in the course of acclimatization by varying heat gain, varying heat loss or by increasing the tolerance of the animal tissues to variations in body temperature or other disturbance resulting from thermal stress.

Adjustment in heat gains. In man the evidence for reduced thyro-adrenal activity and thus reduced basal energy production in heat is somewhat equiv-

ocal, but it appears to be more soundly established for some lower mammals. Presumably in these cases the action is through the anterior pituitary gland, but the mechanism requires much more study. Whether an increased thyro-adrenal activity occurs in cold is debated, but a plausible mechanism can be seen in the stimulation of the autonomic nervous system by cold, with increased adrenalin production and increased pituitary activity, leading to increased thyroid activity.

No information seems to be available upon the possibility of progressive changes in cutaneous circulation, subcutaneous tissues, coat color or the coat itself which enable the animal to acquire protection against heat gain by radiation from hot surroundings or by conduction from hot air.

Adjustment in heat loss. Inasmuch as heat loss is the side of the balance upon which regulation is usually effected, we might here expect to find the chief evidence of acclimatization. There is some evidence that sweating rate may increase in young un-acclimatized animals upon repeated exposure, there is evidence of increased surface area in some growing animals, and the coat usually gets thinner; but, apart from these, it would seem that an individual's heat-loss mechanisms are susceptible to little improvement.

Adjustments in efficiency. The greatest change in repeated exposure to heat seems to be in the efficiency of the animal. It often becomes able to carry out the same effective work with less total energy production. By improvement in blood volume and perhaps a finer balance in circulatory requirement, less danger of relative lack of oxygen is incurred. By reducing agitation it diminishes unnecessary heat production. It would be interesting to know if shallower breathing is developed in those animals in which an alkalosis threatens.

Results of acclimatization. The result of acclimatization to heat is seen in a lowered body temperature, increased efficiency and lessened distress. Should, however, the situation be too severe, not only will this improvement not occur, but the situation may become rapidly worse. When the opposing processes of acclimatization and deterioration are almost equi-potent, quite minor factors may tip the balance one way or another. This is seen even under controlled conditions when the situation is critical. Of acclimatization to cold, little can be said with confidence.

Methods of Studying Reactions of Animals to Environmental Stresses

Five general approaches to the study of animal reactions to environment will be considered here, but no one alone, even if thoroughly developed, is sufficient to provide a solution to either theoretical or severely practical problems. Each approach is capable of contributing important, and some-

times unique information, but each also carries with it certain inherent and usually severe limitations. Only by due attention to each and by a careful synthesis of the results obtained in all these different ways can anything like an adequate picture be obtained. It will quickly transpire that, in their present state of development, they are capable of yielding only the vaguest of suggestions even when carefully considered in toto. What they can give, however, must be thoughtfully reviewed in order to determine the most promising of these suggestions and in order to plan more adequate future studies. Certain examples are cited from the literature to illustrate various points in the discussion, but no attempt has been made to review all the pertinent literature.

Actual Distribution

The existing distribution of a given species, breed or strain can provide important evidence of the adaptability of that species, breed or strain to various environments, but the evidence must be very carefully weighed. In the first place, the non-appearance of a particular type of animal in a given environment may simply mean that the type has never had the opportunity of being tested in it; that there may have been physical or biological barriers between its place of origin and the environment in question. This post-hoc fallacy is a familiar one to the student of human climatology. It must be remembered, also, that it is the total and not merely the physical environment which determines occupation, and this total environment contains such diverse factors as human predilections, religious and social taboos, economic patterns, beasts of prey and cosmic disasters. We would think a student of a little over one hundred years ago foolish if we found his recorded opinion that sheep and cattle could not live in Australia because there were none there at that time, but we might possibly commit a similar blunder now about the plains of China or the highlands of Peru. In particular, as infectious diseases and parasites hitherto so prevalent in tropical areas come under control, the situation is changing, and much more attention must be paid to the limitations imposed by the direct operation of climatic factors upon the animals themselves. It is more probable that through disease control the domains of many domestic animals will be considerably extended in the near future, just as man's dominion has been made almost universal.

When we come to take the evidence of existing distribution, however, we find that it is difficult to collect in satisfactory form. For some countries official publications indicate the distribution of domestic animals in considerable detail, including that of the better known breeds; but in others, figures simply have never been collected. In a large number of countries

data no doubt exist, but they have not been published in a readily available form. This lack of uniformity makes it even more difficult to be sure of the significance of this type of information.

Granting the deficiencies in existing information and the difficulties of applying results obtained in one area to other apparently similar areas, thoughtful breeders have and will continue to take advantage of such information when planning the introduction of a new type to a specific area. The present-day distribution of the Merino, and its close relative the Rambouillet, illustrates the way in which a type adapted to a specific set of conditions has been utilized in other parts of the world where similar conditions of production prevail. Originating in Spain, where feed was scarce and sheep had to be trailed long distances as the seasons changed, the Merino is gregarious, can range over wide areas in search of food, can withstand trailing over long distances, and does not require the relatively lush feed necessary for breeds possessing a more highly developed form. Thus, it was an obvious choice for use in the relatively dry range areas of Australia and South Africa, while the Rambouillet, which is an offshoot of the Merino, was used with equal success on the western ranges of the United States of America. By contrast, the Down breeds of Great Britain have been developed and effectively utilized where different conditions prevail. Animal husbandmen are familiar with these and other instances in which the actual distribution of a particular type or breed can be used as one measure of possible suitability for use in other areas, hence further details and examples will not be cited here.

Field Observations

Observations made under natural conditions, upon animals living a free life and not subjected to the artificialities usually inherent in laboratory examination, undoubtedly have an appeal to those who are themselves concerned with hard practical problems. There is no doubt, moreover, that field observations are of prime importance to the study of animal adaptation. The practical problems arise in the field; any suggestions for action must be tested out in the field and must be compatible with field conditions. Field studies have one serious inherent drawback, however, in that there is an enormous and uncontrolled, often unmeasured, variability in a large number of influential conditions. This makes results very difficult, sometimes impossible, to interpret if considered without reference to more exact experimental enquiries. To a certain extent, modern statistical procedures permit much quantitative information to be extracted from data subject to the combined operation of multiple variables, but this assistance is limited. The

greater the number of variables admitted, the greater the number of observations required before a given difference between two results can be held to have any significance. Moreover, contrary to popular opinion, statistics never *prove* anything; the most they can do is to show the degree of association between certain characters or events, leaving the question of cause and effect entirely open.

Field observations can be divided into three main classes: (1) observations upon material not subject to any interference apart from the fact of observation at a distance; (2) observations upon material specially arranged for the purpose of providing contrasting conditions in different parts; (3) well-defined tests in which the material to be examined is put through some standardized procedure to show up differences in response to some specific conditions.

Every farmer, husbandman, or breeder carries out the first type of observation, though he too seldom has the opportunity or inducement to put his observations down in permanent form, or to submit them to others more highly trained in distinguishing justifiable conclusions from interesting suggestions. Scientists have not omitted to till this field, as can be seen from current literature, although they have perhaps not always made plain the inherent limitations of this method.

It is but a small step from scientifically conducted observations of the first to the more exact methods of the second type of observation. In a well-planned enquiry of the second type, the arrangements will be such as to interfere least with the natural conditions while providing clear-cut comparisons between the items in which the investigator is interested. Scientific planning is essential and statistical considerations must be constantly borne in mind. The exact nature of the plan will depend upon the information required and the circumstances of its collection, but it must be emphasized that it calls for expert handling.

One of the more widely known field tests, in the true sense of the word, is the "Iberia Heat-tolerance Test" (Rhoad, 1944) which is applied to cattle. For this they are kept in a corral on a bright, calm, summer day when air temperatures are between 85 and 95° F., and their rectal temperatures are measured at 10:00 A.M. and 3:00 P.M. The test is repeated on three days, the results averaged and the following formula applied:

$$\text{Index} = 100 - 10\,(\text{Rectal temperature in } ^\circ\text{F.} - 101.0)$$

This represents about as close a compromise as one can get between the scientific requirements of exactness on the one hand and the variability and restrictions of field conditions on the other. It runs the risk of all compromises, of course, of pleasing neither party, but it does seem to be justified as

a rough, inexpensive determination of the wider differences between breeds in their reactions to hot conditions. It should not be used, however, as a basis for sweeping conclusions from relatively small differences. In reporting the results, the prevailing atmospheric conditions should be clearly indicated.

Another example of quite a different type of field test is found in work reported by Phillips and Spencer (1948), in which the performance of Southdown sheep under two sets of conditions was evaluated. This was not a planned experiment, but constituted an attempt to secure leads in the solution of a problem of adaptability, using data on productivity which were collected originally for quite a different purpose. On two occasions the U. S. Bureau of Animal Industry transferred flocks of Southdown sheep between stations at Beltsville, Maryland and Middlebury, Vermont. In one case, the entire flock was moved from Beltsville to Middlebury. At Beltsville the sheep had received excellent care and were grazed on temporary pastures during the summer and fed high quality hay and grain during the winter. At Middlebury they were also given good care, being grazed on permanent pastures during the summer, and receiving good quality hay, silage and grain during the winter. In general there was no pampering at Middlebury but good practical farm management. After two years at Middlebury it was necessary to transfer the flock back to Beltsville because they failed to thrive as meaured by body and fleece weights. Lamb crops were also lower at Middlebury and weaning weights of lambs were decidedly below those at Beltsville.

In another instance, many years earlier, lambs born during two years at Middlebury were transferred to Beltsville to establish a flock. Life-time records of these animals were compared with the records of the flock in the immediately preceding years at Middlebury. There was little difference in performance at the two stations, except in body weight and in this case the ewes were generally heavier at Middlebury. The animals used in this work were of a larger, more rugged type than those used in the later work. There was a difference of approximately 35 pounds in the two types. It seems possible that they were better adapted to the environment at Middlebury, and therefore thrived on the pasture and hay which was their main source of nutrients.

Field tests may be designed to measure differences in reactions of a specific breed or type of animal to two or more environments. An example is found in the work of Whitehurst, Crown, Phillips and Spencer (1947) who report results of an experiment to measure the productivity of Columbia sheep in high, cool and relatively dry range country and in a low subtropical area. The experiment had the further objective of testing the

possibility of grading up native Florida sheep with Columbia rams. In the summer of 1933, 60 Columbia ewes were selected from the U. S. Bureau of Animal Industry's flock at Dubois, Idaho. The animals were paired as closely as possible, one member of each pair being retained at Dubois and the other sent to an experiment station in Florida. Only a very brief summary of the data is given in table 7, to show the marked difference in performance of the two groups mentioned above, plus others involved in the experiment.

In the second phase of the work in which Columbia, native and grade sheep were compared under conditions in Florida, the Columbia sheep used were descendants of those brought from Idaho, for use in the first phase of

TABLE 7. GROSS COMPARISON OF THE PRODUCTIVITY OF THE VARIOUS GROUPS STUDIED AT DUBOIS, IDAHO, AND QUINCY, FLORIDA, IN TERMS OF WOOL AND LAMB PRODUCTION.[1] (FROM WHITEHURST, CROWN, PHILLIPS AND SPENCER, 1947)

Group	Average yearly production per ewe of—			
	Grease wool (kg.)	Staple length of wool (centimeters)	Lambs born (no. per ewe)	Weaning weight (kg.)
Columbia-Dubois	5.25	8.66	1.15	37.1
Columbia-Quincy	5.45	8.55	.77	30.1
Columbia	5.42	7.96	.68	31.6
Native	2.34	6.91	.99	29.9
F_1	3.95	7.92	1.30	34.5
F_2	3.50	8.05	1.07	36.5

[1] Data in the upper portion of the table are from the first phase of the experiment and those in the lower portion are from the second phase.

this work. Native sheep typical of those found in the section around Quincy, Florida, were purchased. The ages of most of these were unknown and some were pregnant when purchased. Data were obtained on the descendants of these purchased native ewes and only those native animals of known age were included in the analysis of data. The F_1 ewes resulted from mating Columbia rams to native ewes, and the F_2 ewes were produced by *inter se* matings, using F_1 rams and ewes.

The findings indicate that Columbia sheep are not sufficiently adapted to conditions in North Florida to reproduce at their maximum efficiency. Their advantage in fleece yield over native ewes was offset by a lower rate of reproduction, and the economic advantage in any one year would be determined by the relative prices of lamb and wool. The results indicate,

further, that Columbia rams may be used effectively for crossing with native ewes. Ewes from this cross were intermediate in fleece weight and superior to either parent type in lamb production.

Field tests such as the last two described usually require quite a few years to carry out, and constitute a combination of practical measures of productivity and breeding experiments such as are discussed in a later section. Information so obtained is indispensable to arriving at satisfactory solutions to many breeding problems which involve questions of climatic stress.

Laboratory Experiments

By contrast with field observations, laboratory experiments are ideally suited to the detailed analysis of specific reactions to specific conditions, and to the systematic plotting of the interactions of a small number of controllable variables. Undoubtedly, the rigid control of variables itself renders the conditions "unnatural," but, properly used, the laboratory can greatly advance our understanding of field problems as well as of that fundamental scientific knowledge without which conquest of the environment would be slow indeed. Detailed experiment upon a carburetor does not teach one to drive a car, but without it cars would be poor performers.

A laboratory analogue to the Iberia Heat-tolerance Test has been developed by the senior author (D.H.K.L.) at the University of Queensland. Animals are exposed seven hours at a time to a series of atmospheres at different known temperatures and humidities. The rectal temperature is measured periodically over each seven hours, and an expression of its mean behaviour, known as the *R*-value, is calculated. From the *R*-values for the different combinations of temperature and humidity we can calculate by statistical methods the value of the constants *a*, *b* and *c* in the equation

$$\text{Log } R = at + bh + c$$

where *t* is temperature and *h* vapor pressure. The values of "*a*" obtained upon two different animals indicate the relative fashion in which their rectal temperature rise in response to atmospheric temperature for a given humidity, and those of "*b*" in response to a rise in atmospheric humidity for a given temperature, over the range of conditions used in the series of experiments.

By similar procedures in respect of pulse rate, respiratory rate and the rate of evaporative water loss we can also investigate in a comparative fashion the way in which the animal responds to heat and humidity in these respects. Some initial results obtained in this way are presented in table 8. They will serve to illustrate the method, though the reasons for certain differences are still being studied.

TABLE 8. RELATIVE REACTIVITY OF ANIMAL FUNCTIONS TO RISE IN ATMOSPHERIC TEMPERATURE.[1] FIGURES ARE THE VALUES OF "a" IN THE EQUATION $\log R = at + bh + c$, EXPRESSED IN TERMS OF THAT FOR ECHIDNA AS 1000

Animal	Rectal temperature	Respiratory rate
Rapid temperature rise, rapid respiratory rise.		
Echidna	1000	1000
Pig		507
Bandicoot	283	850
Possum	142	544
Wallaby	124	526
Muscovy duck	110	861
Rapid temperature rise, slow respiratory rise.		
Australorp hen	148	371
Rabbit	143	479
Cat	134	428
Cuscus	120	406
White Leghorn hen	118	250
Slow temperature rise, rapid respiratory rise.		
Dog	66	659
Kahki Campbell duck	57	1004
Turkey	55	948
Merino sheep	48	689
Merino sheep, low*	41	599
Slow temperature rise, slow respiratory rise.		
Jersey calf	81	217
Jersey cow	49	325
Corriedale sheep, low*	44	406
Merino sheep, high*	40	246
Corriedale sheep, medium*	37	218
Corriedale sheep, high*	35	154
Merino sheep, medium*	30	345

[1] Echidna is a monotreme; bandicoot, possum, wallaby and cuscus are marsupials. The divisions into slownd a rapid have been arbitrarily placed at 100 for rectal temperature index and 500 for respiratory rate index.

* Low, medium, high refer to dietary plane.

Theoretical Considerations

From the known facts of physics and physiology one is often justified in suggesting that the possession of certain characteristics would favor the adaptation of an animal to a given environment, while other characteristics would be of no particular advantage, or even a disadvantage. These "arm-

chair guesses" must not be used, of course, merely to save the trouble of finding out the actual situation, and they must always be treated as tentative hypotheses, to be discarded the moment they are found not to be in accordance with fact. Nevertheless, it is a fairly safe bet that an animal with a thick furry coat is going to find it of considerable advantage in the Arctic, and one would not insist upon an expedition to one of the Poles before working upon that assumption.

In table 9 are listed a number of characteristics which are likely to affect the adaptation of animals to environmental stresses, together with notes upon the probable effects. Pending the actual test of a particular species under particular environmental conditions, a knowledge of these features would help considerably in deciding what its reactions are likely to be. In table 10 is given a similar list of those animal characteristics which are likely to be affected by environmental stress and which may be regarded as an index of physiological strain where more direct evidence is lacking. To a large extent, these tables present a summary of the physiological considerations of the previous Section.

Experimental Breeding

It is a matter of general observation that certain breeds of animals are more resistant to certain environments than others, as judged by weight, performance, milk production, fertility or wool growth. The solution to many problems of adaptability can be expected only through the carrying out of breeding experiments under conditions in which the animals involved are to be produced in practice. Such experiments may involve either the testing of two or more types to ascertain their relative adaptability to the conditions of production, or the development of a type designed to fit the conditions, or a combination of these procedures, the former being used as a basis for breeding plans in the latter. Once a reasonable estimate has been made of the type of animal that is required if satisfactory performance is to be obtained under a given set of relatively unfavorable environmental conditions, the procedures available to the breeder fall into three main categories:

1. Selection within the native types;
2. Grading up with already improved types or breeds from other countries; and
3. Development of new types out of animals that are graded only part of the way up to the improved type.

These have been discussed in detail elsewhere (Phillips, 1947, 1948).

It must be recognized, before improvement programs are begun in areas where the environment places serious limitations on livestock production,

TABLE 9. RELATION OF ANIMAL CHARACTERISTICS TO ADAPTATION TO CLIMATIC STRESS

Item	Relation to heat adaptation	Relation to cold adaptation	Relation to other stress and hazards
	Body Form		
Surface area/mass	High ratio helps, where temperature of surroundings does not exceed body temperature.	High ratio hinders.	Absolute weight a limiting factor in mobility
Size of appendages (ear, tail, limbs, scrotum, neck folds, etc.)	Large size helps, where temperature of surroundings does not exceed body temperature.	Large size hinders.	Length of limb facilitates speed but increases risk of injury.
Coat color	Dark colors hinder by increasing absorption of visible solar radiation.	Dark colors may help by increasing absorption of visible solar radiation.	Camouflage sometimes more important than heat balance. Dark colors protect from sunburn.
Coat nature, density and thickness.	High insulation hinders in humid climates, but may help in hot dry climates. Associated high food intake hinders.	High insulation helps	Affects host-parasite relationship.
Sweat glands	Help to the extent they are functional.	Non-operative.	Skin humidity favors fungal and other growth and epithelial blocking of the ducts.
Vascularity of superificial tissues	Helps where air temperature is below body temperature or where sweating occurs. Hinders where air temperature is above body temperature and there is no sweating.	Hinders.	Favors parasitism.
Subcutaneous fat.	Hinders unless air temperature is above body temperature and there is no sweating.	Helps.	
	Metabolic		
Basal metabolic rate	High rate hinders.	High rate helps.	
Resting metabolic rate	High rate hinders.	High rate helps.	
Work rate	High rate hinders.	High rate helps.	Food supply may determine maximum.

TABLE 9 (*continued*)

Item	Relation to heat adaptation	Relation to cold adaptation	Relation to other stress and hazards
Food nature and amount	High caloric level hinders. Protein proportion immaterial.	High caloric level helps.	Time spent in seeking and consumption may be important. Minimum needs for circumstances must be met.
Thyro-adrenal activity	High rate hinders.	High rate helps.	Correlated with reproductive function. (See below.)
Milk production and egg laying	High rate hinders.	High rate may help if food supply adequate.	
	Thermo-regulatory		
Shivering	Non-operative	Helps until fatigue point reached.	
Respiratory volume	Increased volume helps.	Increased volume hinders.	Minimum requirements for oxygen supply must be met. Increased volume without activity tends to produce alkalosis.
Cutaneous blood-flow	Increased blood-flow helps where air temperature is below body temperature or sweating occurs. May hinder where air temperature is above body temperture and no sweating occurs.	Increased blood-flow hinders.	
Insensible perspiration	Helps.	Hinders.	
Sweating	Helps.	Non-operative.	Skin humidity favors fungal and other growth and blocking of epithelial ducts.
Externally applied water	Helps.	Hinders.	Wallowing favors water parasites.
Posture and herding	Spreading and separation helps.	Flexure and huddling helps.	Herding instinct protects in range country.

TABLE 10. CONSEQUENTIAL EFFECTS (STRAINS) OF CLIMATIC STRESS UPON ANIMAL CHARACTERISTICS

Item	Effect of heat	Effect of cold	Effect of other stress and hazards
Rectal temperature	Raised	Lowered	Exercise and other energy transformation raises.
Cardiac activity	Often increased.	Often increased at first; lowered if stress excessive.	Exercise and other energy transformation increases.
Male reproductive function	Tends to be reduced.	May be reduced	Affected by many factors, especially light.
Female reproductive function	Some antagonistic results.	May be reduced	Affected by many factors, especially light.
Urine volume	Reduced in sweating animals.	Increased	—
Acid-base balance	Tendency to alkalosis	No constant trend.	—
Appetite	Depressed	Increased	Numerous influential factors.
Intestinal function	Tends to be disturbed.	No effect	—
Tissue damage	Sunburn	Frostbite	—
Psychological changes	Lassitude	Some stimulation, but dullness when limits exceeded.	Numerous influential factors.

that some of the existing types are meeting the needs of the people reasonably well. Others may need improvement in some or most of their economically important characteristics, and in such cases it should be recognized that adaptability to environment is especially important and should not be overlooked in developing breeding programs.

Selection within a native type has certain advantages. The native types are already adapted to the local environment, which may not be true of types brought in from other countries, and there is no problem of selection and importation of foreign stock. The disadvantage is that progress is much slower than grading up with already improved types, provided the improved types meet local needs and are adapted to the environment.

Grading up has the obvious advantage of rapid improvement through the use of improved males on large numbers of native females. It is the logical method to be tested in cases where there are existing types in other countries that meet a country's or area's needs and which are apt to perform satisfactorily under the conditions in question. If this method proves satisfactory, foreign breeds or other improved herds need be maintained only as sources of males to continue the grading up program, while the bulk of animals in the area or country would become high-grades as the program progressed.

In many cases it may be found that imported purebred animals cannot perform satisfactorily under existing environmental conditions. Grades with a certain amount of improved breeding may withstand the environment satisfactorily and produce at higher levels than the native stock. In such cases, the obvious procedure is to determine the extent to which improved breeding can be introduced, then develop a new type from animals with this breeding background. Examples of new breeds developed recently are the Santa Gertrudis cattle produced by combining Shorthorn and Zebu blood (Kleberg, 1931) and the Columbia sheep which was developed from a crossbred foundation of finewool and longwool blood (Spencer and Stoehr, 1941). The lessons to be learned from these and other similar developments can be applied in many areas where, by the development of a new type, the needs of the livestock producers and consumers can be more adequately met.

Literature Cited and References for Further Reading

Accame, F., Luis Monge and J. C. Miller. 1944. Effect of Reduced Barometric Pressure on Ram Semen. JOURNAL OF ANIMAL SCIENCE. 3: 431.

Anderson, J. 1945. Seasonal Variation in the Reproductive Capacity of the Bull. Jour. Agric. Sci. 35: 184–196.

Asdell, S. A. 1946. Patterns of Mammalian Reproduction. Comstock Publishing Co., Ithaca, N. Y.

Ashton, J. 1930. Growth and Development. XIII. The Influence of Certain Geographical and Historical Conditions on the Physical Development of Lombardy, Brown-Swiss, Brittany, Dairy Shorthorn, Ayrshire, and Beef Shorthorn Breeds of Cattle. Missouri Agric. Expt. Sta. Res. Bull. 141.

Bettini, T. M. 1938. La Zootecnica nel Sud Africa. Relazioni e Monografia Agrario-coloniali, Inst. Agric. Colon. Ital., 46.

Bisschop, J. H. R. 1938. The Relation Between Environment and Animal Breeding with Special Reference to the Breeding of Cattle in the Semiarid Regions of S. Africa. XIIIth International Veterinary Congress, Zurich.

Black, W. H., A. T. Semple and J. L. Lush. 1934. Beef Production and Quality as Influenced by Crossing Brahman with Hereford and Shorthorn Cattle. U. S. Dept. of Agric. Technical Bull. No. 417.

Blum, Harold F. 1945. The Physiological Effects of Sunlight on Man. Physiol. Reviews. 25: 483–530.

Blumenstock, David I., and C. Warren Thornthwaite. 1941. Climate and the World Pattern. U. S. Dept. of Agric. Yearbook of Agriculture. Pp. 98–127.

Bonsma, J. C. 1940. The Influence of Climatological Factors on Cattle. Farming in S. Africa. 15: 373–385.

Bonsma, J. C. 1943. Influence of Color and Coat Cover on Adaptability of Cattle. Farming in S. Africa. 18: 101–120.

Brody, S. 1945. Bioenergetics and Growth. Reinhold Publishing Corp., New York, N. Y.

Bywater, T. L. 1944. Sheep for Long Leys. British Society of Animal Production, Proceedings, Pp. 25–42.

Capstick, J. W. and T. B. Wood. 1922. The Effect of Change of Temperature on the Basal Metabolism of Swine. Jour. Agric. Sci. 12: 257.

Carter, H. B. 1943. Studies in the Biology of Skin and Fleece of the Sheep. Australian Coun. Sci. Indust. Res. Bull. 164.

Committee on Hill Sheep Farming in Scotland. 1944. Report. Dept. of Agric. for Scotland, Cmd. 6494.

Committee on Hill Sheep Farming in England and Wales. 1944. Report. (British) Ministry of Agriculture and Fisheries, Cmd. 6498.

Dawson, W. M., Ralph W. Phillips and S. R. Speelman. 1945. Growth of Horses Under Western Range Conditions. JOURNAL OF ANIMAL SCIENCE. 4: 47–54.

Faulkner, D. E. 1947. The Cattle of the Swazi. Swaziland Livestock and Agricultural Dept., Mpisi Series 1.

Forbes, E. B., W. W. Braman and M. Kriss. 1926. The Influence of the Environmental Temperature on the Heat Production of Cattle. Jour. Agric. Res. 33: 579–589.

French, M. H. 1940. Cattle Breeding in Tanganyika Territory and Some Developmental Problems Relating Thereto. Empire Jour. Exp. Agric. 8: 11–22.

Gaalaas, R. F. 1945. Effect of Atmospheric Temperature on Body Temperature and Respiration Rate of Jersey Cattle. Jour. Dairy Sci. 28: 555–563.

Gaalaas, R. F. 1947. A Study of Heat Tolerance in Jersey Cows. Jour. Dairy Sci. 30 (2): 79–85.

Grandstaff, J. O. 1942. Wool Characteristics in Relation to Navajo Weaving. U. S. Dept. of Agric. Tech. Bull. 790.

Hall, F. G., D. B. Dill and E. S. G. Barron. 1936. Comparative Physiology in High Altitudes. Jour. Cell. Compar. Physiol. 8: 301.

Hammond, John. 1932. Report on Cattle-Breeding in Jamaica and Trinidad. Empire Marketing Board Bulletin No. 58. (England).

Hammond, John. 1945. Constitution in Cattle in Relation to Pests and Diseases. Ann. App. Biol. 32: 278.

Heitman, Hubert, Jr. 1949. The Effects of Air Temperature and Relative Humidity on the Physiological Well Being of Animals. JOURNAL OF ANIMAL SCIENCE. 8: (in press).

Hindmarsh, W. L. 1939. Water Requirements of Sheep. Agric. Gazette of New South Wales. 50: 293.

Howe, J. W. 1946. The Effects of Varying Amounts of Zebu Blood on the Adaptability of Dairy Cattle to Conditions in Jamaica. Iowa State College Thesis, Iowa State College, Ames, Iowa.

Kartha, K. P. R. 1942. Milk Records of Cattle in Approved Dairy Farms in India. Imp. Coun. Agric. Res., Misc. Bull. 18, 1938; 36, 1941; 37, 1941; 52, 1942.

Kaura, R. L. 1941, 1942. Some Common Breeds of Indian Sheep. Indian Farming, 1941, 2: 175–179; 1942, 3: 122–125.

Kelley, M. A. R. and I. W. Rupel. 1937. Relation of Stable Environment to Milk Production. U. S. Dept. of Agric. Tech. Bull. 591.

Kelley, R. B. 1943. Zebu-Cross Cattle in Northern Australia. Australian Council for Scientific and Industrial Research, Bulletin No. 172.

Keys, A. 1936. The Physiology of Life at High Altitudes. The International High Altitude Expedition to Chile, 1935. Sci. Monthly. 43: 289–312.

Kleberg, Robert J., Jr. 1931. The Santa Gertrudis Breed of Beef Cattle. The Producer. 13 (1): 3–7.

Kriss, M. 1930. The Insensible Loss in Body Weight in Cattle. Jour. Agric. Res. 40: 27, 283.
Lagerlöf, Nils. 1934. Morphologische Untersuchungen über Veränderungen im Spermabild und in den Hoden bei Bullen mit verminderter oder aufgehobener Fertilitat. Acta Path. et Microbiol. Scand., Suppl. XIX. Almquist and Wiksells Boktryckeri—A.B., Uppsala, Sweden.
Lee, D. H. K. 1948. Heat and Cold. Ann. Rev. Physiol. 10: 365–386.
Lee, D. H. K., K. Robinson, H. J. G. Hines and N. T. M. Yeates. 1941. Reactions of Domestic Fowls, the Rabbit, the Pig, the Cat, the Dog, the Sheep to Hot Atmospheres. Proc. Roy. Soc. Queensland. 53: 105–200.
Lee, D. H. K., K. W. Robinson, N. T. M. Yeates and M. I. Scott. 1945. Poultry Husbandry in Hot Climates—Experimental Enquiries. Poultry Sci. 24: 195–207.
Lines, E. W. and A. W. Pierce. 1931. The Basal (Standard) Metabolism of the Australian Merino Sheep. Australian Coun. Sci. Indust. Res. Bull. 55.
McMeekan, C. P. 1938. Shape of the Growth Curve as a Controlling Factor in Conformation and Anatomical Composition of the Animal Body. Amer. Soc. Anim. Prod., Proc., Pp. 337–341.
Miller, J. C., and Luis Monge. 1946. Body Temperature and Respiration Rate, and Their Relation to Adaptability in Sheep. JOURNAL OF ANIMAL SCIENCE. 5: 147–153.
Minett, F. C. 1947. Effects of Artificial Showers, Natural Rain, and Wallowing on the Body Temperatures of Animals. JOURNAL OF ANIMAL SCIENCE. 6: 35–49.
Minett, F. C., and S. Sen. 1945. Rectal Temperatures of Certain Animals at Rest. Indian J. Vet. Sci. & Anim. Hus. 15: 62–78.
Mitchell, H. H., L. E. Card and T. S. Hamilton. 1931. A Technical Study of the Growth of White Leghorn Chickens. Illinois Agric. Expt. Sta. Bull. 367: 83–139. (Other references to the work of this laboratory are given therein.)
Mitchell, H. H., and M. A. R. Kelley. 1933. Estimated Data on the Energy, Gaseous, and Water Metabolism of Poultry for Use in Planning the Ventilation of Poultry Houses. Journ. Agric. Res. 47: 735–748.
Mitchell, H. H. and M. A. R. Kelley. 1938. Energy Requirements of Swine and Estimates of Heat Production and Gaseous Exchange for Use in Planning the Ventilation of Hog Houses. Jour. Agric. Res. 56: 811–830.
Monge, C. 1948. Acclimatization in the Andes: Historical Confirmations of Climatic Aggression with Development of Andean Man, 148 pages. Johns Hopkins Press, Baltimore, Md.
Olver, A. 1938. A Brief Survey of Some of the Important Breed of Cattle in India. Imp. Coun. Agric. Res., Misc. Bull. 17.
Phillips, Ralph W. 1944. The Cattle of India. Jour. Hered. 35: 273–288.
Phillips, Ralph W. 1945. The Water Buffalo of India. Jour. Hered. 36: 71.
Phillips, Ralph W. 1947. Breeding Better Livestock. U. S. Dept. of Agric. Yearbook for 1943–47, Science in Farming. Pp. 61–70.
Phillips, Ralph W. 1948. Breeding Livestock adapted to Unfavorable Environments. FAO Agric. Studies No. 1. pp. 182.
Phillips, Ralph W., R. G. Johnson and R. T. Moyer. 1945. The Livestock of China. U. S. Dept. of State Publication No. 2249.
Phillips, Ralph W., Bradford Knapp, Jr., Louis C. Heemstra and Orson N. Eaton. 1943. Seasonal Variation in the Semen of Bulls. Amer. Jour. Vet. Res. 4: 115–119.
Phillips, Ralph W. and F. F. McKenzie. 1934. The Thermo-Regulatory Function and Mechanism of the Scrotum. Missouri Agric. Expt. Sta. Res. Bull. 217.
Phillips, Ralph W. and Damon A. Spencer. 1948. Reactions of Southdown Sheep to Two Environments. JOURNAL OF ANIMAL SCIENCE. 7: 40–48.
Phillips, Ralph W., I. A. Tolstoy and R. G. Johnson. 1946. Yaks and Yak-Cattle Hybrids in Asia. Jour. Hered. 37: 163–170. 207–215.
Phillips, Ralph W., Ralph G. Schott, Orson N. Eaton and Victor L. Simmons. 1943. Seasonal Variations in the Semen of Sheep and Goats. Cornell Veterinarian. 33: 227–235.
Phillips, Ralph W., R. G. Schott and V. L. Simmons. 1947. Seasonal Variations in the Occurrence of Conceptions in Karakul Sheep. JOURNAL OF ANIMAL SCIENCE. 6: 123–132.

Phillips, Ralph W. 1948. The Relation of Environmental Factors to Reproduction in Livestock. 1st Inter. Congress on Physiol. and Pathology of Animal Reproduction, Proc., Milan.

Regan, W. M. and G. A. Richardson. 1938. Reactions of the Dairy Cow to Changes in Environmental Temperature. Jour. Dairy Sci. 21: 73.

Rhoad, A. O. 1938. Some Observations on the Response of Purebred *Bos taurus* and *Bos indicus* Cattle and their Crossbred Types to Certain Conditions of Environment. Amer. Soc. Anim. Prod., Proc., Pp. 284–295.

Rhoad. A. O. 1940. Absorption and Reflection of Solar Radiation in Relation to Coat Color in Cattle. Amer. Soc. Anim. Prod., Proc., Pp. 291–293.

Rhoad, A. O. 1944. The Iberia Heat Tolerance Test for Cattle. Tropical Agric. 21: 162–164.

Rhoad, A. O. 1941. Climate and Livestock Production. Washington: U. S. Dept. of Agric. Yearbook, Climate and Man. Pp. 508–516.

Rhoad, A. O. and W. H. Black. 1943. Hybrid Beef Cattle for Subtropical Climates. U. S. Dept. of Agric. Circ. No. 673.

Riek, R. F. and D. H. K. Lee. 1948. Reactions to Hot Atmospheres of Jersey Cows in Milk. Jour. Dairy Res. 15: 219–226.

Riek, R. F. and D. H. K. Lee. 1948. Reactions of Jersey Calves to Hot Atmospheres. Jour. Dairy Res. 15: 227–232.

Riemerschmid, G. 1943. Some Aspects of Solar Radiation in its Relation to Cattle in S. Africa and Europe. Onderstepoort Jour. Vet. Sci. 18: 327.

Riemerschmid, G. and J. S. Elder. 1945. The Absorptivity for Solar Radiation of Different Colored Hairy Coats of Cattle. Onderstepoort Jour. Vet. Sci. 20: 223–234.

Ross, I. Clunies. 1936. A Survey of the Sheep and Wool Industry of North-Eastern Asia. With Special Reference to Manchukuo, Korea and Japan. Commonwealth of Australia, Council of Scientific and Industrial Research, Pamphlet No. 65.

Schott, R. G., R. W. Phillips and D. A. Spencer. 1939. The Occurrence of Estrus in Sheep and its Relation to Extra-Seasonal Production of Lambs. Amer. Soc. Anim. Prod., Proc., Pp. 347–353.

Seath, D. M. and G. D. Miller. 1947. Heat Tolerance Comparison Between Jersey and Holstein Cows. Journal of Animal Science. 6: 24–34.

Sinha, K. C. and F. C. Minett. 1947. Application of Water to the Body Surface of Buffaloes and its Effect on Milk Yield. Journal of Animal Science. 6: 258–264.

Slater, A. E. and S. S. S. Bhatia. 1941. The Improvement of Goats in the United Provinces. Progress Report of the Work Done for the Year 1940–41 at the Goat Breeding Farm, Etah, with Tables of Livestock Statistics and Balance Sheet. Lucknow. Govt. Branch Press.

Spencer, Damon A. and John A. Stoehr. 1941. Columbia Sheep and Their Place in Range Sheep Production. Bureau of Animal Industry, U. S. Dept. of Agric. Processed Publication No. A.H.D. 42.

Sundstroem, E. S. 1930. Contributions to Tropical Biochemistry and Physiology; Part II. Supplementary Experiments on Rats Adapted to Graded Levels of Reduced Cooling Power. Univ. Calif. Pub. Physiol. 7 (10): 103–195.

Ware, F. 1941. A Brief Survey of Some of the Important Breeds of Cattle in India, Parts II and III. Imp. (India) Coun. Agric. Res. Misc. Bull. 24, 1939; 46, 1941.

Ware, F. 1942. A Further Survey of Some Important Breeds of Cattle and Buffaloes in India. Imp. (India) Coun. Agric. Res. Misc. Bull. 54.

White, R. G. 1932. Sheep Farming: A Distinctive Feature of British Agriculture. British Assoc. for Advancement of Science, Proceedings, Pp. 229–256.

White, R. G. 1931. The Importance of Hardiness in Welsh Mountain Sheep. Jour. Royal Welsh Agric. Soc.

White, R. G. 1939. Systems of Sheep Farming: 1. Mountain Sheep Jour. of (British) Ministry of Agriculture. 46: 532–538.

White, R. G. 1944. General Survey of the Sheep Industry, British Society of Animal Production, Proc., Pp. 5–9.

White, W. T., Ralph W. Phillips and E. C. Elting. 1946. Yaks and Yak-Cattle Hybrids in Alaska. Jour. Hered. 37: 355–358.

Whitehurst, V. E., R. M. Crown, Ralph W. Phillips and D. A. Spencer. 1947. Productivity of Columbia Sheep in Florida and Their Use for Crossing with Native Sheep. Florida Agric. Expt. Sta. Bull. No. 429.

Wright, Norman C. 1945. Report on the Development of Cattle Breeding and Milk Production in Ceylon. (British) Colonial Office. Eastern No. 179.

Yeates, N. T. M. 1947. Influence of Variation in Length of Day upon Breeding Season in Sheep. Nature 160: 429.

OBSERVATIONS ON PIGMENTATION OF EYELIDS OF HEREFORD CATTLE IN RELATION TO OCCURRENCE OF OCULAR EPITHELIOMAS[1]

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EYE cancer in Hereford cattle causes significant economic loss. Apparently the incidence is highest in Southwestern United States and in other areas of continued bright sunlight such as occurs at high altitudes. It is generally assumed that the tendency for ocular epithelioma in Herefords is hereditary and that lack of pigment on the eyelids contributes to susceptibility. This latter correlation doubtless derives from the consensus that white skin is more sensitive to various irritants.

Data are presented in this paper on the incidence of eye cancer, together with observations relative to pigmentation of the eyelids. The data were collected from the high-grade Hereford cattle in the San Joaquin Experimental Range herd and from the University purebred Hereford herd at Davis. These herds are inter-related through use of University herd sires since 1935. It is anticipated that further analysis and verification of the records, together with results of critical matings not yet available, may make possible a future contribution upon the mode of inheritance of eyelid pigmentation in Hereford cattle.

Data and Discussion

Occurrence of Eyelid Pigmentation

Since 1943, variation in distribution patterns of red pigmentation about the eyes of 470 animals in the Experimental Range herd and 121 animals in the University purebred herd have been tentatively classified as follows:

Amount of pigmentation	*Range Herd, percent*	*Purebred, percent*
Class I, both eyes completely encircled with red	20.4	11.6
Class II, one eye red, one eye broken red (discontinuous)	12.1	2.5
Class III, both eyes broken red	41.1	36.4
Class IV, one eye red, one clear (white)	0.9	7.4
Class V, one eye broken red, one clear	12.1	13.2
Class VI, both eyes clear	13.4	28.9

While the distribution presented above is essentially correct and gives an idea of the pattern variations in these populations, partial recheck of available animals has revealed some errors. Most of these involve oversight of

[1] This work was supported by the Kellogg Fund of the University of California for the application of genetics to farm animals.

small breaks in eyes classed as completely red or very small spots of red on eyelids originally recorded as white or clear. Some calves which at birth appear to be clear eyed subsequently developed pigmented eyelids. Similarly very small spots generally enlarge in relative size and increase in intensity of pigmentation as the animal develops.

Later it became evident that more specific and quantitative description of color patterns was desirable. Without qualification the term "broken red," for example, covered everything from small spots of red to nearly complete circles, and gave no clue whether or not the vulnerable parts of the lower lids were pigmented.

Studies of matings show that increase in the amount of pigment around the eyes may be accomplished simply by selection of sires with red rings around the eyes or those having more red than white in this area.

Gross Description of Eye Neoplasms

The first abnormality usually noted is the appearance of wart-like growths covered by waxy exudate that may extend out from the lower eyelid or along the eyelashes a half inch or more. These are easily pulled or broken off, leaving an ulcerated area on the margin of the lid unprotected by hair. Treatment of these areas with silver nitrate styptic appeared in some cases to promote healing. Frequently, however, the growths or ulcerations recur, progressing during the summer and subsiding during the winter but becoming progressively worse until they may suddenly become malignant. Then the whole area may be involved in the course of two or three months. This change from raw sores or small wart-like growths to rapidly developing organized tumors that quickly invade surrounding tissue is the criterion used to differentiate between what is assumed to be the initial predisposing condition and malignancy. Sometimes these areas invite fly-strike and maggot infestation.

Occasionally the nictitating membrane is initially involved; in most cases the origin is on the lower eyelids, which are more directly exposed to solar radiation.

Incidence of Eye Cancer

All animals in the Experimental Range herd are critically examined once yearly at weaning time when body measurements are taken and color pattern variations are recorded. Eye irritations are also routinely recorded from field observations whenever they occur throughout the year. During the period 1935 to 1946, twenty-four cases were recorded. The age at which abnormality was first observed was as follows: one case at 3 years; 6 cases at 5 years; 5 cases at 6 years; 2 cases at 7 years; 5 cases at 8 years; 3 cases at 9 years;

and 2 cases at 10 years. Ten of these became definitely malignant, and the animals were discarded on this account. In two cases, malignancy developed within a few months of the first observed difficulty. In the others, malignancy and disposal occurred 1 to 3 years after the first observed manifestation. Two additional animals were sold because of eye ulceration developing to an extent that almost invariably foreshadowed severe difficulty if kept through the following summer.

For purposes of comparison, animals over 4 years old were considered in the susceptible age group, since only one case was recorded among large numbers of younger animals. There were during 1935 to 1946 inclusive 228 females over four years old that were retained in the herd for significant periods of time. On this basis, the total incidence of conspicuous eye lesions was 10.5 percent; 5.25 percent were severe enough to cause disposal; and of the total 4.4 percent definitely became malignant.

In the University purebred herd, 3 cases of eye cancer have occurred among 68 cows retained in the herd until more than 4 years of age. Two of these were mother and daughter. The percentage incidence also comes out 4.4. The average disposal age from the purebred herd has been 9.5 years. Cows normally are culled for age from the Range herd at 9 or 10 years, but since many are removed earlier for other reasons, the average disposal age is less than in the purebred herd. Thus early sale may eliminate some potential victims of carcinoma.

Relation of Eyelid Pigmentation to the Incidence of Neoplasms

Since the observations on eye ulcerations and neoplasms cover a longer period than those on color patterns, eye pigmentation classification is recorded for only 13 of the affected animals. Of these, one was class II; 7 were class III; 2 were class V; and 3 were class VI; the original classification does not indicate whether or not vulnerable areas are pigmented.

It is significant, however, that none of the cases observed had eyes completely encircled with red, and that initial neoplasms or ulcerations always occurred on unpigmented portions of the lower eyelids. None has been observed on pigmented areas. Thus an eye may be classified as broken red with more red than white, and still offer no protection unless the middle and anterior corner of the lower lid is pigmented. When the growth becomes malignant, it invades the tissue regardless of pigmentation and may involve the eyeball. Two cases have been observed in which the cancer started in the nictitating membrane. One of these had more red than white surrounding the eye and the lower lid was mostly pigmented.

The statement has been made that cancers always occur on one side. Our malignant cases have occurred about equally in the right and left eyes, but

never in both, although eight cases are recorded with sores or wart-like growths on the lids of both eyes.

Many clear-eyed cattle, or those without protection of the lower lids, never develop epitheliomas, which suggests that other environmental and inherent factors are involved in the development of malignant cases. Unfortunately, the data do not permit comparison of percentage incidence on the basis of the number out of the 296 cows in the susceptible age group that lacked protective pigmentation of vulnerable areas on the eyelids.

Conclusion

The data presented show that eye cancer in Hereford cattle is of economic importance. This is somewhat minimized by the age of incidence. Wart-like growths and ulcerations cause distress and sometimes fly-strike before becoming malignant.

In a recent review of the cancer problem, Rous (1946) presented evidence that normal cells rarely became neoplastic without first being disordered. More than 290 chemical substances are known to be carcinogenic. Included are various coal tars, polycyclic hydrocarbons, and even hormones elaborated from normal tissue. The extreme sensitivity of some members of certain Irish families to ultra-violet light from sunlight leading first to benign then to malignant skin growths was cited. Evidence on hereditary susceptibility and on the possible role of viruses was also presented and discussed in the review.

In the light of present knowledge, it appears reasonable to assume that sunburning of continuously moist non-pigmented areas of the lower eyelids is a pre-disposing cause of cell derangement and the appearance of ulcerations and benign neoplasms—that under continued irritation these may become malignant in animals having a hereditary predisposition.

The evidence of relation of pigmentation to susceptibility, although admittedly incomplete, is sufficiently impressive to warrant breeding for red around the eyes—a characteristic once common to the Hereford breed which has been minimized by discriminative selection. Further work on the mode of inheritance of pigment about the eyes, the interrelationship with other features of the Hereford color pattern, and hereditary susceptibility to eye cancer is justified.

Literature Cited

Rous, Peyton, 1946. Concerning the Cancer Problem. American Scientist 34: 329–358.

THE EFFECT OF WINTER SUPPLEMENTATION ON SUBSEQUENT GAINS OF BEEF STEERS ON GRASS AND IN THE FATTENING LOT

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Introduction

THE high plains area of eastern Colorado lends itself to the production of grain sorghum, barley, wheat and some corn for concentrate feeds; to sorghum fodder and silage for roughage feeds; and to short grass pasture associations such as grama and buffalo grasses for grazing. This gives opportunity to feed cattle under a flexible program that can include wintering, grazing and fattening. The utilization of those home-grown feeds and the practicability of protein supplementation of rough winter rations for steers were considered in feeding experiments conducted by the Colorado Agricultural Experiment Station with the cooperation of the U. S. Dryland Experiment Station at Akron, Colorado.[1]

Experimental work at other stations indicates that the rate of winter gains is in inverse ratio to subsequent gains on grass. Weber *et al.* (1947) at the Kansas station found that steers which made the largest winter gains tended to make the smallest pasture gains and as a consequence, differences in total gains (wintering plus grazing) were of doubtful significance. Experimental results at the Oklahoma station by Ross *et al.* (1946–47) indicate that calves winter on grass and cottonseed meal, to gain $\frac{1}{2}$ to $\frac{3}{4}$ of a pound a day, will produce desirable feeder yearlings at a greater profit than those gaining 1 to $1\frac{1}{2}$ pounds per head daily on a more concentrated ration.

Plan of Experiment

Five replications were made over a period of three years testing the value of adding a protein supplement to a wintering ration for steer calves and observing the carry-over effect during the subsequent grazing and fattening periods. The basal wintering ration was composed of chopped forage sorghum (cane) fodder and silage fed according to appetite, salt free choice and a mineral mixture of two parts ground limestone, 2 parts steamed bone meal and one part salt fed free choice. In May the steers were grazed together on native short-grass pasture. In November the steers were returned to the Akron feed lots where they were fattened for market.

[1] Grateful acknowledgment is made of the cooperation given by Sup't. J. F. Brandon of the U. S. Dryland Experiment Station, Akron, Colorado.

Results

The results of winter supplementation on subsequent gains are shown in table 1. Adding one pound of over 40 per cent protein supplement (both cottonseed meal and soybean meal were fed) to the wintering ration apparently stimulated the appetite of the steers, thus increasing the total consumption of feed. Mineral consumption, however, was reduced in the protein fed lot. The steers fed the supplemented ration gain 85.3 pounds more per head at an additional feed cost of $6.65 or 7.8 cents per pound added gain. By the end of the grazing period this spread in gains was narrowed to 36.8 pounds, which increased the cost per pound of added gain to 18.1 cents. By the end of the fattening period the spread in gains was further narrowed to 29.8 pounds which further increased the cost to 22.3 cents per pound of extra gain.

The feed cost per cwt. of gain for the protein supplemented steers during the winter was $8.27 less than for those receiving no protein. During the following grazing and fattening periods, however, this cost was greater for the winter supplemented steers and over the entire three-phase period resulted in a 21 cent greater feed cost per cwt. of gain for these steers. Livestock market men evaluated the steers at the end of each period. With but one exception, no differences were made in their price estimates. This exception gave a 50-cent per cwt. advantage to the non-supplemented steers at the end of one of the three wintering periods due to a greater demand for light weight feeders at that time.

Using Morrison's (1944) energy tables, the following average energy values were calculated for the feeds used in these trials:

Grain	—1,540 therms per ton
Protein supplement	—1,540 therms per ton
Cane silage	— 280 therms per ton
Cane fodder	— 600 therms per ton.

Based on the above values, using the therms of energy required to produce 100 pounds of gain, the protein supplement when added to the wintering ration showed the following energy replacement values through the three feeding periods:

By the end of wintering	—10,714 therms per ton
By the end of grazing	—minus 125 therms per ton
By the end of fattening	—84 therms per ton.

Thus, the energy replacement value of the protein supplement during the wintering period was over seven times that of its calculated value, but this

TABLE 1. EFFECT OF ADDING PROTEIN SUPPLEMENT TO THE WINTERING RATIONS OF STEERS FED IN A WINTERING, GRAZING, FATTENING PROGRAM

Lot treatment	Avg. No. days	Avg. initial wt.	Avg. final wt.	Avg. daily gain	Average daily feed per steer						Feed consumed per CWT gain						Feed cost per CWT gain	Total feed cost per steer
					Grain	Prot. sup.	Cane sil.	Cane fod.	Min. mix.	Salt	Grain	Prot. sup.	Cane sil.	Cane fod.	Min. mix.	Salt		
Protein supplement—47 steers																		
Wintering	113	438.6	578.5	1.24		.99	10.09	10.00	.05	.07		80.0	815.0	807.7	4.0	5.8	13.07	18.29
Grazing	184	578.5	746.2	.91		(Native grass pasture)											2.68	4.50
Sub-total	297	438.6	746.2	1.04								36.4	370.7	367.4	1.8	2.6	7.41	22.79
Fattening	183	746.2	1103.1	1.95	16.36	1.06	13.87	.83	.06	.06	838.9	54.4	711.2	42.6	3.3	3.0	30.88	110.21
Total	480	438.6	1103.1	1.38							450.6	46.0	553.6	192.9	2.6	2.8	20.02	133.00
No protein supplement—49 steers																		
Wintering	114	444.4	499.0	.49			9.57	8.19	.07	.10			1998.1	1710.0	14.8	20.7	21.34	11.65
Grazing	183	449.0	715.2	1.18		(Native grass pasture)											2.08	4.50
Sub-total	297	444.4	715.2	.91									402.8	344.8	2.9	4.2	5.97	16.15
Fattening	182	715.2	1079.1	2.00	16.36	1.06	13.87	.83	.06	.06	818.2	53.0	693.7	41.5	3.2	2.9	30.12	109.61
Total	479	444.4	1079.1	1.33							469.1	30.4	569.6	170.9	3.1	3.4	19.81	125.76

increased value was lost by the end of the following grazing and fattening periods.

In terms of total feed replacement, when one pound of protein supplement was added to the wintering ration, one ton of protein supplement valued at $90.00 was equivalent to:

By the end of wintering: 15 tons cane silage +11 tons cane fodder+600 pounds mineral = $300.48.

By the end of grazing: 1 ton cane silage+$\frac{3}{4}$ ton cane fodder+140 pounds mineral = $21.45.

By the end of fattening: 1$\frac{1}{2}$ tons grain+1$\frac{1}{4}$ tons cane silage+1$\frac{1}{3}$ tons cane fodder+120 pounds mineral = $106.97.

The feed prices used were as follows:

Grain	—$60.00 per ton
Protein supplement	— 90.00 per ton
Cane silage	— 8.00 per ton
Cane fodder	— 15.00 per ton
Mineral mixture	— 45.00 per ton
Salt	— 20.00 per ton
Pasture	— 4.50 per head

From a practical feeding standpoint, it would pay under High Plains conditions to add one pound of over 40% protein supplement (cottonseed meal or soybean meal) to a steer calf wintering ration of sorghum silage and sorghum fodder if the steers are sold at the end of the wintering period. If they are carried on through the grazing and fattening periods it is questionable whether winter protein supplementation would pay.

Literature Cited

Morrison, F. B., 1944. Feeds and Feeding, 20th Edition, The Morrison Publishing Co., Ithaca, N. Y.

Ross, O. B., D. F. Stephens, W. D. Campbell, V. G. Heller, and A. E. Darlow, 1947. Summer Gains of Yearling Steers Wintered at Different Levels. Progress Reports; Feeding Tests with Sheep, Swine and Beef Cattle, 1946–47, Misc. Pub. No. MP-11, Okla. Agriculture Experiment Station, pp. 34–38.

Weber, A. D., F. W. Bell, and A. G. Pickett, 1947. Influence of Winter Rations Fed to Steer Calves Upon Returns From Wintering and Grazing, Thirty-Fourth Annual Feeders' Day Report, Kansas Agriculture Experiment Station, p. 26.

VALUE OF DISTILLERS DRIED SOLUBLES AND DISTILLERS DRIED GRAINS WITH SOLUBLES IN THE RATIONS OF DAIRY CALVES[1]

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Introduction

DISTILLERS dried solubles and distillers dried grains with solubles should be, because of their relatively high protein and vitamin-B-complex content, of value in the rations of dairy calves. These feeds have been found to be of high nutritive value in the rations of most livestock (Black *et al.*, 1945; Fairbanks *et al.*, 1945; Krider *et al.*, 1947; Parkhurst *et al.*, 1946; Synold *et al.*, 1943; Williman *et al.*, 1942).

Distillers feeds have been used in dairy cattle rations since 1884 when Schmoyer and Neubert (1884) reported an increased yield in milk production from distillers' waste. Later Wokes *et al.* (1942) observed an increase in both milk and milk fat production when they fed distillers' waste to dairy cows. Sutton (1947) found that distillers dried solubles replaced satisfactorily soybean oil meal in the rations of dairy cows. It has been demonstrated that distillers grains are comparable to gluten feed, linseed oil meal, casein, and dried skim milk as a source of protein (Billings *et al.*, 1907; Hart *et al.*, 1916; Hart *et al.*, 1917; Hart *et al.*, 1918).

In the past little attention has been given to distillers feeds as a source of proteins and vitamins in the dairy calf rations. Davis and Trimberger (1946) reported that distillers dried grains, both solubles and insolubles, gave satisfactory results in a dry calf starter after the calves were two months of age.

A study was designed to compare distillers dried solubles (corn) and distillers dried grains with solubles (corn) with dried whey, brewer's dried yeast, and linseed oil meal as sources of protein in the ration of dairy calves.

Experimental

Forty-eight calves were used in this feeding trial. Calves, 3 to 14 days of age, were purchased in Central Pennsylvania. Two males and two females of the Holstein and Guernsey breeds respectively comprised each experimental group. At the beginning of the trial, the calves were divided into six

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[2] The data contained in this paper are from a thesis submitted by the senior author to the Graduate School of The Pennsylvania State College in partial fulfillment of the requirements for the degree of Master of Science, 1947.

groups comparable on the basis of breed, sex, body weight, height at the withers, and circumference of the chest at the beginning of the trial.

The calves were housed in an artificially ventilated and well lighted barn, which was heated in cold weather to avoid extreme fluctuations in temperature. An outdoor lot was available for exercise on suitable days. The calves were weighed every seven days, and height measurements at the point of the withers and chest measurements at the sixth rib were taken every month.

All calves received twenty-two grams of sulfathalidine the first three days. This sulfonamide was administered in a warm water drench. The initial dose of four grams was given upon arrival of the calves at the College Experimental barn and two grams were given three times per day for the next three days. In conjunction with the sulfathalidine the calves received seven supplemental vitamin tablets containing: 5,000 U.S.P. Units of Vitamin A, 400 U.S.P. Units of Vitamin D, 250 mgm. of Vitamin C, and 50 mgm. of Niacin. One vitamin tablet was given upon arrival at the College barn and one twice each day for the following three days.

All of the calves were fed three hundred pounds of whole milk from Holstein cows during the first forty-five days of the trial. Mixed hay, timothy, and Ladino clover was kept before the calves at all times until they were two months of age, after which they were fed a good quality alfalfa hay ad lib until they were eight months of age.

The concentrate rations, presented in table 1, were fed throughout the entire eight months. Ration I was used as a control ration in which brewer's dried yeast and linseed oil meal were the protein supplements. Ration II differed from ration I in that one hundred and fifty pounds of distillers dried solubles replaced the dried whey and brewer's dried yeast. Ration III contained three hundred pounds of distillers dried solubles replacing dried whey, brewer's dried yeast, and linseed oil meal. Ration IV was a replicate of ration II except that 150 pounds of distillers dried grains with solubles were used instead of 150 pounds of distillers dried solubles. Ration V was similar to ration III and contained 300 pounds of distillers dried grains with solubles in place of the 300 pounds distillers dried solubles.

In computing these concentrate mixtures it was necessary to have one ingredient as a variable so that the percent of protein, calcium, and phosphorus could be maintained at approximately the same levels; thus wheat bran was the one variable.

Blood plasma carotene and vitamin A determinations were made when the calves were three and six months of age. Moore's (1939) method, with slight modifications, was used for determining blood plasma carotene. Fifteen ml. of petroleum ether were used to extract the carotene instead of

TABLE 1. INGREDIENTS OF RATIONS FED, IN POUNDS

Ingredient	Ration No.				
	I	II	III	IV	V
Crushed oats	650	650	650	650	650
Corn meal	595	595	595	595	595
Wheat bran	165	175	145	175	145
Soybean oil meal	250	250	250	250	250
Linseed oil meal	120	120		120	
Dried whey	100				
Brewers dried yeast	60				
Dried solubles		150	150		
Dried grain with solubles				150	300
Steam bone meal	25	25	25	25	25
Limestone	15	15	15	15	15
Salt	10	10	10	10	10
Vit. A oil (3,300 U.S.P. gm.)	9	9	9	9	9
Irradiated yeast	1	1	1	1	1
Totals	2,000	2,000	2,000	2,000	2,000
Est. % dig. protein	17.4	17.5	17.0	17.6	17.3
Est. % calcium	0.58	0.50	0.50	0.49	0.48
Est. % phosphorus	0.62	0.67	0.72	0.62	0.54

five ml. All tubes were shaken for two minutes, instead of one minute, after they had been in the cold water bath. Vitamin A analyses of the blood plasma of the calves were determined according to Kimble's method (1938).

Experimental Results

The summary of the data, presented in table 2, represents the growth of the calves during the eight months feeding trial. The daily gains in body weight produced by ration III (15% distillers dried solubles) were apparently greater than those produced by the control ration, whereas those by ration IV (7.5% distillers dried grains with solubles) were somewhat lower. These data were analyzed statistically according to the method of Snedecor (1940). No significant differences were found in the rate of gain among the the several rations fed. The analysis was made on the actual daily gains as well as on the percent of normal gains. The variation within groups was large enough to render mean group differences in weight gains insignificant.

The calves on ration III (15% distillers dried solubles) appeared to grow more rapidly in terms of height at the withers, as well as body weight, than did the other groups on the trial. As shown by analysis of variance, the differences between mean rates of growth in terms of height of the withers,

TABLE 2. SUMMARY OF GROWTH DATA

Group	Mean daily gain lbs.	Percent of normal*	Mean daily growth in height cm.	Mean daily growth in chest cir. cm.
Group I (basal)	1.57	110.3	0.123	0.22
Group II (7.5% distillers dried solubles)	1.57	109.3	0.120	0.21
Group III (15% distillers dried solubles	1.65	108.1	0.130	0.21
Group IV (7.5% distillers dried grains with solubles)	1.52	105.4	0.117	0.22
Group V (15% distillers dried grains with solubles)	1.59	107.4	0.124	0.21

* Normals based on standards described in Mo. Agric. Expt. Sta. Bul. 336.

were small and not statistically significant. Similarly no differences were found between the various groups when circumference of the heart girth was used as a criterion.

There was no apparent difference in the amount of feed consumed per calf in the various groups and, therefore, no difference in palatability was observed.

The costs per pound of gain in body weight are presented in table 3. Feed costs were based on retail prices in effect May 26, 1947. Ration I was the most expensive grain mixture on the basis of cost per ton. Ration I was also the most expensive when cost per pound gain in body weight was con-

TABLE 3. SUMMARY OF GAINS IN BODY WEIGHT AND FEED COSTS

Group	Gain lbs./day	Cost per lb. gain*
Group I (basal)	1.57	$0.20
Group II (7.5% distillers dried solubles)	1.57	0.16
Group III (15% distillers dried solubles)	1.65	0.17
Group IV (7.5% distillers grains with solubles)	1.52	0.17
Group V (15% distillers grains with solubles)	1.59	0.18

* Feed costs based on current retail feed prices in May 1947.

sidered. Ration II (7.5% distillers dried solubles) reduced the cost four cents per pound gain in body weight when compared to ration I (control). The cost of raising the calves was reduced three cents per pound gain in body weight with rations III (15% distillers dried solubles) and IV (7.5% distillers dried grains with solubles), whereas, ration V (15% distillers dried grains with solubles) lowered the cost by two cents per pound of body weight gained.

Unfortunately due to pneumonia and enteritis, the following losses occurred during the conduction of the trial: Group I—one Holstein female, group II—none, group III—one Guernsey female and two Guernsey males, group IV—one Guernsey male and one Holstein male, and group V—one Guernsey female.

No difference was apparent in the blood plasma vitamin A of calves in the various groups at three and six months of age. The blood plasma carotene values were somewhat below the values reported by Moore (1945). The lower carotene concentrations were probably the result of supplemental feeding of vitamin A as shown by Gallup (1941) and Wise *et al.* (1947).

Summary and Conclusions

1. No significant differences were found between the mean rates of growth of the groups of calves during the eight months of this trial when gain in body weight, gain in height at the withers and gain in chest circumference were used as criteria.

2. No differences were observed in the palatability of the rations studied.

3. Distillers dried solubles and distillers dried grains with solubles appeared to produce more economical gains in body weight than dried whey, brewer's dried yeast, and linseed oil meal.

4. On the basis of these data, it would appear that distillers dried solubles and distillers dried grains with solubles might replace satisfactorily dried whey, brewer's dried yeast, and linseed oil meal in the rations of dairy calves.

Literature Cited

Billings, G. A. 1907. Report to the Dairy Husbandman; Distillers' Grains vs. Ground Oats, Gluten Feed, Oil Meal and Bran. New Jersey Sta. Report, p. 39.

Black, W. H., N. R. Ellis and W. P. Garrigus. 1945. Distillery Slops for Fattening Steers. JOURNAL OF ANIMAL SCIENCE 4: 158.

Davis, H. P. and G. W. Trimberger. 1946. Distillers' By-Products and Soybean Meal in Dry Calf Starters for Calves on Limited Quantities of Milk. Univ. of Neb. Agric. Expt. Sta. Res. Bul. 142.

Fairbanks, B. W., J. L. Krider and W. E. Carroll. 1945. Effect of Diet on Gestation-Lactation Performance of Sows. JOURNAL OF ANIMAL SCIENCE 4: 410.

Gallup, W. D. 1941. Changes in Blood Plasma Carotene Values Observed in Studies of Vita-

min A Deficiency. Symposium on Biochemistry. Dallas Meeting of A.A.A.S., December 29.

Hart, E. B. and G. C. Humphreys. 1916. Further Studies ofthe Relation of the Quality of the Proteins of Milk Production. Jour. Bio. Chem. 26: 457.

Hart, E. B. and G. C. Humphreys. 1917. The Relation of the Quality of Proteins in Milk Production III. Jour. Bio. Chem. 31: 445.

Hart, E. B. and G. C. Humphreys. 1918. The Relation of the Quality of Proteins in Milk Production IV. Jour. Bio. Chem. 35: 367.

Kimble, M. S. 1938. The Photoelectric Determination of Vitamin A and Carotene in Human Plasma. Jour. Lab. and Clinical Med. 24: 1055.

Krider, J. L. 1947. The Use of Distillers Solubles in Swine Rations. Second Conference on Feeds of the Beverage Distilleries, Proc., pp. 32–37.

Moore, L. A. 1939. The Determination of Blood Plasma Carotene in the Bovine Using a Photoelectric Colorimeter. Jour. Dairy Sci. 22: 501.

Moore, L. A. and M. H. Berry. 1945. Vitamin A and Carotene Content of the Blood Plasma of Dairy Calves from Birth up to Four Months of Age. Jour. Dairy Sci. 28: 821.

Parkhurst, R. T. and J. W. Kuzmeski. 1946. Supplements for Distillers' By-Products in Poultry Breeding Diets. Poultry Sci. 25: 162.

Ragsdale, A. C. 1934. Growth Standards for Dairy Cattle. Mo. Agric. Expt. Sta. Bul. 336.

Schmoyer, M. and O. Neubert. 1884. Influence of Distillers' Waste on Milk Secretion. Jour. Chem. Soc. Abstract 46(3): 194.

Snedecor, G. W. 1940. Statistical Methods Applied to Experiments in Agriculture and Biology. Iowa State College Press, Ames, Iowa.

Sutton, T. S. 1947. Distillers' Feeds in Dairy Cow and Beef Cattle Rations. Second Conference on Feeds of the Beverage Distilleries, Proc., pp. 38–42.

Synold, R. E., C. W. Carrick, R. E. Roberts, and S. M. Hauge, 1943. Distillers' Dried Solubles as a Vitamin Supplement for Chick Rations. Poultry Sci. 22: 233.

Willman, J. C. and F. B. Morrison. 1942. Comparison of Protein Supplements for Fattening Lambs. 55th Annual Rpt., Cornell Agric. Expt. Sta., p. 105.

Wise, G. H., F. W. Atkinson, M. J. Caldwell, D. B. Parrish and J. S. Hughes. 1947. Effects of High Vitamin A Intake on Milk and Fat Yields of the Vitamin A Constituents in Milk, Blood, and Livers of Dairy Cows. Jour. Dairy Sci. 30: 279.

Wokes, F., B. M. Still and J. C. Organ. 1942. Dried Potato Slices as Feeding Stuff for Dairy Cattle. Agriculture (England), Vol. 49. Cited from Chem. Abstract 38: 1579.

DEVELOPMENT OF HYALURONIDASE IN BULL SEMEN[1]

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A ROLE of seminal hyaluronidase in reproductive physiology has been assumed with the discovery that this enzyme was capable of denuding the freshly ovulated mammalian ovum of cumulus cells (Pincus and Enzmann, 1935; McClean and Rowlands, 1942; Fekete and Duran-Reynals, 1943; Leonard and Kurzrok, 1945). In accordance with this observation, it would seem that the large number of spermatozoa which are required to effect fertilization are necessary to supply sufficient hyaluronidase to denude the ovum of follicular cells and thus allow a spermatozoon to make contact with the ovum (Rowlands, 1944).

In fertility studies in rabbits, Rowlands (1944) found that by adding seminal plasma from killed sperm suspensions containing hyaluronidase to dilute sperm suspensions, only one-sixth the sperm concentration was required for a given level of fertilization as compared to control groups. In similar experiments, however, Chang (1947) reported that the increased power of fertilization of seminal plasma containing hyaluronidase was not due to the contained hyaluronidase but to some other factor in the seminal plasma, since seminal plasma from vasectomized bucks not containing hyaluronidase had a similar ability to increase the percentage of fertilized ova. At the same time, added bull testis hyaluronidase did not increase the percentage of fertilized ova when dilute sperm suspensions were used in comparison with adequate controls.

Kurzrok *et al.* (1946) reported six cases of human infertility, where the female was apparently not at fault, in which the application of bull testis hyaluronidase to the uterine cervix resulted in pregnancies.

Forty-eight similar cases of human infertility in women were reported by Siegler (1947) in which the application of bull testis hyaluronidase resulted in no conceptions. Semen samples in these cases, however, were not assayed for hyaluronidase.

Rabbit sperm studies by Hechter and Hadidian (1947) indicated that seminal hyaluronidase is derived from a portion of the reproductive tract above the vas deferens, and that hyaluronidase in semen is either derived from or is closely associated with spermatozoa. These workers reported also that normal rabbit spermatozoa either contains or produces, under *in vitro* conditions, a large amount of hyaluronidase relative to the amount of enzyme which diffuses into the original seminal plasma.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Dairy Industry, New Brunswick, N. J.

The works cited above indicate the possible relationship between the hyaluronidase content of semen and its fertilizing capacity in mammals. Preliminary to a study of this possible relationship in dairy bulls, it was first necessary to determine the influence of the length and temperature of storage and of bacterial contamination of bull semen upon its hyaluronidase content. Bacterial contamination may be an important consideration here, since it has been reported that certain bacteria are hyaluronidase producers (Meyer, 1947).

Methods and Materials

Semen hyaluronidase was assayed by the turbidometric method of Kass and Seastone (1944) as modified by Leonard, Kurzrok and Perlman (1946). This assay method is based on the observation of Meyer and Palmer (1936) that the turbidity produced by the interaction of hyaluronic acid and acidified blood serum is, within limits, a function of the hyaluronic acid concentration. The hyaluronidase unit is designated the "Turbidity Reducing Unit" (TRU) and is defined as the amount of enzyme which will reduce the turbidity produced by 0.2 mg. hyaluronic acid in conjunction with acidified blood serum to the equivalent turbidity of 0.1 mg. hyaluronic acid in 30 minutes at 37° C.

The substrate used was potassium hyaluronate.[2] The acidified blood serum was prepared from defibrinated and centrifuged blood from a single cow. Dairy bull semen[3] was obtained from the Experiment Station bull stud. These bulls are used for artificial insemination of cattle by the Sussex County Cooperative Breeders Association, Inc.

A Klett-Summerson Photoelectric Colorimeter with red color filter No. 66 was used for turbidity determinations.

A 37° C. thermostatically controlled water bath was used to carry out the enzymatic reactions.

The method of plotting the data for a given assay for hyaluronidase is illustrated in figure 1. It has been shown (Leonard, Perlman, and Kurzrok, 1946) that in this assay the logarithm of turbidity values is a function of the enzyme concentration. Since the Klett-Summerson machine is calibrated on a logarithmic scale, no conversions of turbidity values are necessary. The concentrations of diluted semen (x-axis) are plotted as the reciprocals of the dilution rates, thus expressing true relative concentrations of seminal plasma. This reciprocal may be referred to as a concentration factor. The reciprocal of the concentration factor, of course, equals the dilution rate. In figure 1

[2] The K-hyaluronate was furnished through the courtesy of Dr. Erwin Schwenk of the Schering Corp., Bloomfield, N. J.

[3] The assistance of Mr. C. Edmund Shuart, N. J. Agric. Exp. Sta., Mr. Alfred G. Bates and Mr. Arden Foster, Sussex County Coop. Breeders Assn., Inc., in obtaining bull semen is gratefully acknowledged.

that dilution rate of seminal plasma which reduces the turbidity from the level of the 0.2 mg. hyaluronate to the equivalent turbidity of the 0.1 mg. hyaluronate equals the assay dilution. Since only 0.5 ml. of diluted seminal plasma is used in the assay, the assay dilution rate (which is 1:45 in figure 1) must be doubled to secure TRU's per ml. of seminal plasma.

Initial hyaluronidase assays were begun within one-half hour after the semen samples were ejaculated. Subsequent assays were run at intervals as indicated.

Results and Discussion

To determine whether or not hyaluronidase can be found in seminal plasma immediately after ejaculation (centrifuging begun within ten minutes after ejaculation), several assays were made on different samples of bull

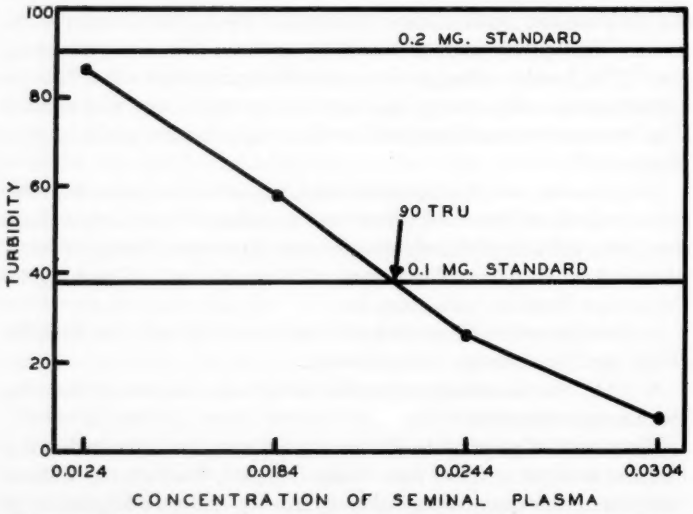

Figure 1. Method of plotting assay data to determine hyaluronidase concentration of a typical sample of bull semen. Note that semen concentrations are plotted as the reciprocals of the dilution rates.

semen. In all cases the semen samples showed initial concentrations of between 50 and 150 TRU's of hyaluronidase per ml.

The possibility of an increase in hyaluronidase concentration in sperm-free seminal plasma due to a proenzyme or other factors was investigated. Semen samples were first centrifuged briefly to remove most of the spermatozoa and then filtered with a Boerner microcentrifuge filter which removed

all spermatozoa. The resultant sperm-free seminal plasma was assayed immediately and then samples were stored for twenty-four hours at 5° C. and 37° C. and reassayed. In all instances the initial assays and the assays after storage were practically identical.

The influence of the length and temperature of semen storage upon the hyaluronidase concentration was determined on several semen ejaculates from different bulls. These samples were assayed for hyaluronidase immediately after ejaculation and then subdivided and stored at both 5° C. and 37° C. and these subsamples reassayed at various time intervals. The results of

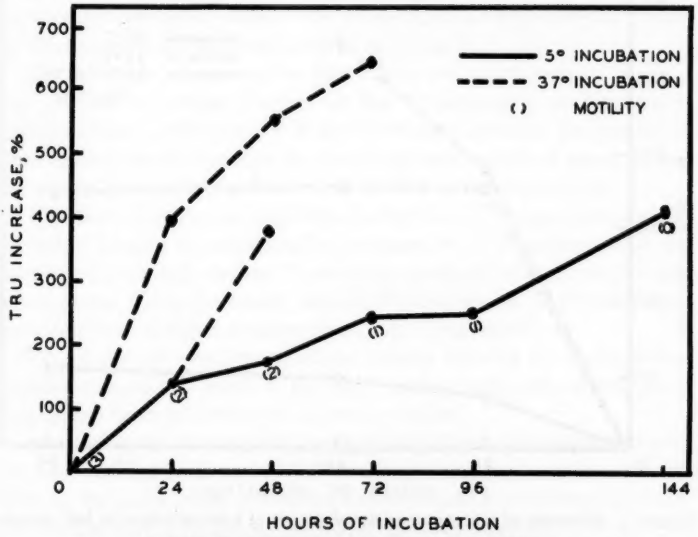

Figure 2. Influence of length and temperature of storage upon the development of hyaluronidase in bull semen.

one such experiment, which are typical of the results obtained in the other experiments, are presented in figure 2. The data are plotted as the percentage increase in TRU's over the initial assay, against length of time of storage. From the figure it may be seen that the 37° C. sample increased approximately 400 percent in hyaluronidase concentration in 24 hrs., while a sample which was kept for 24 hrs. at 5° C. and then transferred to 37° C. also reached the 400 percent level in the second 24 hrs. of storage. The sample stored at 5° C. reached the 400 percent level in approximately 144 hrs., coincident with a drop in motility rating from a 3 to a 0 as shown in figure 2.

Since it has been reported (see Meyer, 1947, for review) that certain bacteria are capable of producing hyaluronidase, it was necessary in these experiments to determine whether any of the increase in hyaluronidase concentration with storage, particularly at 37° C., was due to bacterial action. Many kinds of bacteria have been identified as being present in normal semen (Gunsalus, Salisbury, and Willett, 1941) including certain bacteria which have been reported to be hyaluronidase producers. Experiments similar to the last ones described were conducted except that 37° C. incubated samples

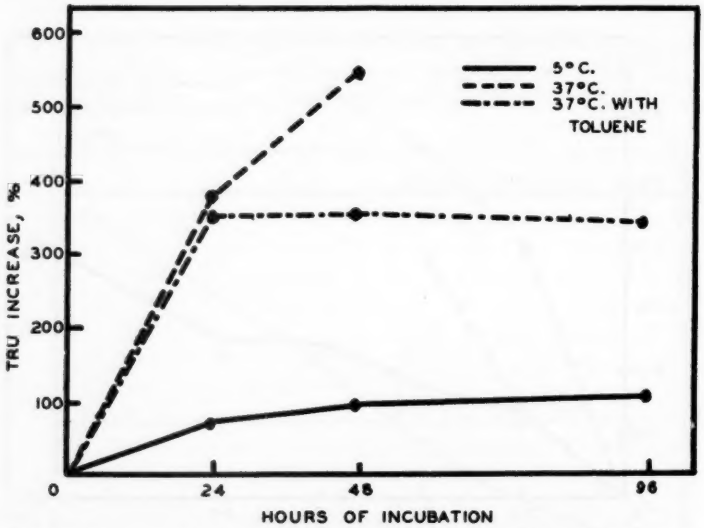

Figure 3. Influence of toluene upon development of hyaluronidase in bull semen in relation to length and temperature of storage.

to which toluene had been added to retard bacterial growth were included.

The results of one typical experiment are presented in figure 3. It will be noted that the two 37° C. incubated samples reached approximately the same percentage increase in hyaluronidase concentration in 24 hours of storage, at which time the hyaluronidase concentration of the sample to which toluene was added plateaued with no further increase in hyaluronidase, while the 37° C. sample with no toluene continued to increase in hyaluronidase concentration in a manner similar to that shown in figure 2.

Discussion

The work of Hechter and Hadidian (1947) and Chang (1947) showed that the seminal fluids of vasectomized animals do not contain hyaluronidase.

The presence of hyaluronidase in the samples of seminal plasma assayed immediately after ejaculation tends to confirm the results of Hechter and Hadidian (1947), who found that there was a rapid diffusion of hyaluronidase into the seminal fluids.

The fact that no increase in hyaluronidase concentration occurs in sperm-free seminal plasma whereas an increase does occur when whole semen is incubated indicates that hyaluronidase in bull semen is closely associated with the spermatozoa and is not merely secreted into the seminal fluids by the testes.

Our observation that the hyaluronidase concentration of semen increases significantly even when stored under refrigeration is contrary to the reports of Werthessen *et al.* (1945) and Leonard *et al.* (1946).

The inferences which may be drawn from the experiments on temperature and time of storage of semen are that hyaluronidase concentration in semen increases as the motility of the sperm decreases or as the number of dead sperm increases and that the length and temperature of semen storage are merely factors which influence the viability of the spermatozoa.

The effect of toluene in inhibiting development of hyaluronidase and the growth of bacteria in semen samples incubated at 37° C. indicated that certain bacteria normally present in semen are producers of hyaluronidase and affect greatly the hyaluronidase content of stored semen, particularly those samples stored at higher temperatures and for long periods.

Thus it may be seen that significant changes occur in the hyaluronidase concentration of bull semen as the result of the length and temperature of storage and bacterial activity in the semen samples.

It would appear that in studying the relationship or correlation between the hyaluronidase concentration of semen and other factors such as the fertility of the semen, these influencing factors should be considered and procedures for assay of hyaluronidase standardized accordingly.

Summary

It has been suggested that the activity of the enzyme, hyaluronidase, is a factor in fertility. As a preface to such a fertility study, the effect of certain factors on the hyaluronidase content of ejaculated seminal plasma of bulls was determined. The findings indicate (1) that hyaluronidase is found in seminal plasma immediately after ejaculation; (2) that seminal plasma which has been completely cleared of spermatozoa by centrifuging shows no increase in hyaluronidase when stored for 24 hrs. at either 5° C. or 37° C.; (3 that seminal plasma from semen which has been stored at 5° C. shows a gradual and considerable increase in hyaluronidase concentration, whereas storage at 37° C. causes an extremely rapid and large increase; and (4) that the addition of toluene to semen incubated at 37° C. prevents any further in-

crease in hyaluronidase concentration after approximately 24 hours of storage, but does not prevent the large initial increase in hyaluronidase concentration during the first 24 hours of storage. This observation indicates that bacteria present in semen may produce hyaluronidase, but that the addition of toluene prevents or limits the production of bacterial hyaluronidase. The large initial increase in hyaluronidase concentration in semen incubated with toluene at 37° C. apparently is derived from the spermatozoa alone.

Literature Cited

Chang, M. C. 1947. Effects of Testis Hyaluronidase and Seminal Fluids on the Fertilizing Capacity of Rabbit Spermatozoa. Proc. Soc. Exp. Biol. and Med. 66: 51–54.

Fekete, E. and F. Duran-Reynals. 1943. Hyaluronidase in Fertilization of Mammalian Ova. Proc. Soc. Exp. Biol. and Med. 52: 119–121.

Gunsalus, I. C., G. W. Salisbury and E. L. Willett. 1941. The Bacteriology of Bull Semen. Jour. of Dairy Science 24: 911–919.

Hechter, O. and Z. Hadidian. 1947. Hyaluronidase Activity of Spermatozoa. Endocrinology 41: 204–205.

Kass, E. H. and C. V. Seastone. 1944. The Role of the Mucoid Polysaccharide (Hyaluronic Acid) in the Virulence of Group A Hemolytic Streptococci. Jour. of Exp. Medicine 79: 319–330.

Kurzrok, R., S. L. Leonard and H. Conrad. 1946. Role of Hyaluronidase in Human Infertility. Amer. Jour. of Medicine 1: 491–506.

Leonard, S. L. and R. Kurzrok. 1945. A Study of Hyaluronidase-Effects on the Follicle Cells of Ovulated Rat Ova. Endocrinology 37: 171–176.

Leonard, S. L., P. L. Perlman and R. Kurzrok. 1946. A Turbidimetric Method For Determining Hyaluronidase in Semen and Tissue Extracts. Endocrinology 39: 261–269.

McClean, D. and I. W. Rowlands. 1942. Role of Hyaluronidase in Fertilization. Nature 150: 627–628.

Meyer, K. 1947. The Biological Significance of Hyaluronic Acid and Hyaluronidase. Physiol. Reviews 27: 335–359.

Meyer, K. and J. W. Palmer. 1936. On Glycoproteins; Polysaccharides of Vitreous Humor and of Umbilical Cord. Jour. Biol. Chem. 114: 689–703.

Pincus, G. and E. V. Enzmann. 1935. Comparative Behavior of Mammalian Eggs in Vivo and in Vitro; Activation of Ovarian Eggs. Jour. Exp. Med. 62: 665–675.

Rowland, I. W. 1944. Capacity of Hyaluronidase to Increase the Fertilizing Power of Sperm. Nature 154: 332–333.

Siegler, S. L. 1947. Clinical Evaluation of Hyaluronidase in Infertility. Paper presented at Third Annual Convention of Amer. Soc. for Study of Sterility.

Werthessen, N. T., S. Berman, B. E. Greenberg and S. L. Gargill. 1945. A Technique for the Assay Hyaluronidase in Human Semen and its Correlation with the Sperm Concentration. Jour. of Urology 54: 565–570.

COMPARATIVE STUDY OF HEN EGG YOLK CITRATE AND TURKEY EGG YOLK CITRATE DILUTER IN THE PRESERVATION OF BULL SPERMATOZOA[1]

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CONSIDERABLE advancement has been made in diluters for the preservation of bull spermatozoa in recent years. Phillips (1939) and Lardy and Phillips (1939) developed a diluter composed of equal parts of a phosphate buffer solution and yolk of hen's egg which greatly enhanced the longevity of bull spermatozoa in storage, but no information is available as to whether egg yolk of birds other than the hen can be used as a material for diluter.

Studies were made on semen collected by means of an artificial vagina from six bulls which were in regular use in the dairy herd at the Agricultural and Mechanical College of Texas. The semen was diluted at the rate of 1:10 with M/8 sodium citrate solution and equal parts of egg yolk according to the method developed by Salisbury *et al.* (1941). A diluter composed of hen egg yolk and sodium citrate was compared with a diluter of turkey egg yolk and sodium citrate for maintaining sperm motility in storage at 40° F.

Motility gradings were made at the time of collection and daily thereafter by placing a drop of diluted semen in a haemocytometer so that the same volume of semen was examined each time. The grading was based upon the percentage of active motile spermatozoa.

A total of 18 ejaculates were studied in duplicate for each diluter. The average longevity in the hen egg yolk citrate diluter was 246.66 ± 16.33 hours as compared to 242.66 ± 17.01 hours in turkey egg yolk citrate diluter. The mean difference of 4 hours is not significant ($P < 0.5$). The average initial motility of 18 samples of semen was 85.6 percent. After a storage period of 336 hours, the motility was reduced to 0.1 and 0.7 percent in hen egg yolk citrate and turkey egg yolk citrate diluter respectively. The average motility in storage for each diluter has been calculated as the sum of motility percentages during the storage period divided by the number of hours. This has been found to be 36.63 percent in hen egg yolk citrate diluter as compared to 36.41 percent in turkey egg yolk citrate diluter. The mean difference between the two diluters is only 0.22 percent. The coefficient of correlation between motilities in the two diluents was found to be $r = +.9995$. This indicates that motility decreased in storage at almost the same rate in both the diluters.

[1] Condensed from a thesis for Master of Science Degree at A & M College of Texas.

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It appears from this study that yolk from turkey egg can be used as a material for diluter and consequently egg yolk of other species of birds might also be used.

Literature Cited

Phillips, P. H. 1939. Preservation of Bull Semen. Biol. Chem. 130: 415.

Lardy, H. A. and P. H. Phillips. 1939. Preservation of Spermatozoa. Amer. Soc. An. Prod., Proc., pp. 219–222.

Salisbury, G. W., H. K. Fuller and E. L. Willett. 1941. Preservation of Bovine Spermatozoa in Yolk Citrate Diluent and Field Results from Its Use. Jour. Dairy Sci. 24: 905–910.

THE EFFECTS OF FEEDING THYROPROTEIN ON SEMEN CHARACTERISTICS OF RAMS

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IT has been observed that the sexual activity of male sheep and goats, and to a certain extent male cattle, is less in the hot period of summer (July and August) than in other seasons of the year. McKenzie and Berliner (1937) and Bogart and Mayer (1946, 1946*a*) have shown that high summer temperatures lower the activity of the thyroid gland. This in turn influences the activity of the testes so that fewer spermatozoa, a smaller volume of ejaculate and an increased number of dead and abnormal spermatozoa result. These workers and several others have shown that injections of thyroxine or the feeding of thyro-active iodinated casein resulted in an improvement in semen volume and in percentage of living and normal sperm. By feeding 1 gm. of thyroprotein daily to a Toggenburg buck that showed no interest in estrus does, Turner *et al.* (1943) succeeded in getting 5 pregnancies from 6 females bred. Also a ram which had failed to settle ewes showed an improvement of semen quality and a number of ewes settled after he had been fed 1 gm. of thyroprotein per day over a period of several days. Schultze and Davis (1946) and Reineke (1946) treated dairy bulls with varying amounts of thyroprotein for different lengths of time with the result that improvement was shown in quality of semen and to a slight extent conception rate. By feeding 50 mg. potassium iodide and 0.8 lb. skimmilk powder daily for 2 to 6 months, Knoop (1946) succeeded in securing improvement in libido, in semen quantity, in number of sperm and in percentage of live and active sperm.

As a result of these experiments it was decided to test the effectiveness of feeding thyroprotein in improving the semen quality of rams in the U. S. Department of Agriculture's flock of sheep at Beltsville, Maryland.

Materials and Methods

Twelve rams, 6 Hampshires and 6 Shropshires, were selected for the experiment. Six of the rams were yearlings; the other six varied from 2 to 5 years of age. The rams were divided into 3 groups so that each group would be represented by each breed and each breed by a yearling and a mature ram. Thus, there were 4 rams in each of the 3 groups. All were fed 1 pound per head daily of a grain mixture containing 14.1 percent crude protein. In addition to the grain mixture, group 1 received 2 gm. thyroprotein[1] per

[1] The protein was furnished by Cerophyl Laboratories, Inc., Kansas City, Mo. The thyroxine analysis based on butyl alcohol soluble iodine was 3.01 percent.

pound of grain mixture; group 2 received 1 gm. of thyroprotein per pound of grain; and group 3 received only the grain mixture without the addition of thyroprotein. Feeding of thyroprotein began on May 23, 1946 and terminated September 4, 1946. Semen samples were collected weekly by means of the artificial vagina, beginning may 29 and ending September 11.

Observations were recorded on semen volume, motility score,[2] semen concentration (million sperm per cc.) and percentage of abnormal spermatozoa. Weights of the rams were also taken weekly. The analysis of variance method was used in working up the data. The experiment was also divided into 3 periods of time, each consisting of 5 weekly observations beginning with June 5 and ending with September 11. Thus feeding of thyroprotein had been in progress nearly 2 weeks (13 days) when the first sample used in the analysis of data was taken, and had ended 1 week by the time the last sample was taken. It is believed, however, that this did not affect the results.

The semen samples taken on May 29 were used as a measure of the normal performance of the rams, but this single sample is probably inadequate, since there is often considerable variation from week to week. The average of the samples over the whole test period were generally lower than the readings for this first sample.

Results and Discussion

From the beginning of the experiment characteristic individual differences in the semen were observed. Shropshire No. 33X of group 1 and No. 14V of group 2, both mature rams, had thin watery semen containing many broken and fragmentary spermatozoa throughout the test period. This condition was not present in the first samples taken May 29.

Results of the experiment are compared in table 1 with similar data for 6 rams of the same breeds under normal feeding conditions for the same period of 1942. Possibly some of the low values are caused by the poor samples from Shropshires 33X and 14V of groups 1 and 2, respectively. However, if these animals are omitted, groups 1 and 2 are still inferior to group 3 in most of the characters observed.

The weights of the rams were taken weekly throughout the test period. There was a constant gain from the beginning of the period to the end, but the variance for the different groups was not significant for any of the variables considered when calculated on a basis of percentage of the previous week's weight.

Groups 2 and 3 were very similar in general, while group 1, which received the 2-gm. level of thyroprotein daily, was considerably out of line.

[2] The scale of motility was as follows: 1, most active; 2, less active; 3, quiet progressive motion; 4, weak progressive motion; 5, motile but not progressive; 6, non-motile.

TABLE 1. COMPARISON OF SEMEN OF TEST RAMS AS AFFECTED BY TREATMENT, SEASON, BREED AND AGE WITH THE SEMEN OF NORMALLY TREATED RAMS OF THE SAME BREEDS IN TWO DIFFERENT YEARS

Variable considered	Semen volume		Concentration		Abnormal sperm		Motility score[1]		Growth, percent of previous weight, 1946
	1942	1946	1942	1946	1942	1946	1942	1946	
	cc		*(Million sperm per cc)*		*(percent)*				
Treatment:		*		*		*		*	
Group 1, 2 gm. thyroprotein		.812		2421		20.3		2.15	100.7
Group 2, 1 gm. thyroprotein		.745		3612		13.4		1.48	100.8
Group 3, no thyroprotein	1.050	.743	3361	4204	17.0	8.3	2.06	1.13	100.8
Season:				*					
1st 5-week period	1.006	.717	3985	4144	10.5	12.9	1.61	1.35	100.8
2nd 5-week period	1.222	.778	3557	3404	20.6	13.6	2.39	1.55	101.0
3rd 5-week period	.922	.805	2541	2690	19.8	15.4	2.17	1.87	100.6
Breed:				*				*	
Shropshire	.993	729	2818	2780	28.4	14.7	2.67	1.80	100.7
Hampshire	1.107	.804	3903	4045	5.6	13.2	1.44	1.38	100.8
Age:		*				*		*	
Yearlings	1.047	.908	3471	3590	15.4	9.6	2.14	1.30	101.0
Older rams	1.055	.626	3141	3236	20.2	18.3	1.89	1.88	100.6

[1] The highest degree of motility scores 1, the lowest 6.
* Indicates a significant variance.

This may have been due in part to the fact that one of the 2 rams having poor semen throughout the test period was in group 1. The other ram was in group 2, but did not cause this group to differ significantly from the untreated group. Even after the poor ram is removed from group 1, the group is still inferior to groups 2 and 3 in all semen characteristics except semen volume. This possibly indicates that there may be a level above which thyroprotein is injurious rather than beneficial in improving semen quality. The results obtained would suggest that this level is between 1 and 2 gm. daily. The group receiving 1 gm. was only slightly superior to the untreated group. This seems to be in agreement with the results of Schultze and Davis (1946), who noted only slight changes during their test period, but found no change in an untreated group over the same period.

Comparison was made of the test rams with untreated rams on which semen studies had been made four years previously (1942) during a similar period of time. This was done to determine if there was a seasonal trend and a trend due to breed. The rams in the 1942 group were less variable in age than in the groups tested in the present experiment, 4 out of the 6 tested being yearlings. There was little difference between the 2 age groups of 1942, but they produced a larger volume of semen than the 1946 test animals.

The progressive decline in semen volume from late in May to early in September was in agreement with the findings in 1942. This is during the period of decline as reported by Phillips *et al.* (1943). The decline was apparent in the test groups regardless of the feeding of thyroprotein. There was also a breed difference apparent in the 1942 group, the Hampshires having more sperm per cc. than the Shropshires.

The 1942 group Hampshires also had a better motility score than the Shropshires, agreeing with the results of the present experiment.

The higher motility score and greater number of sperm per cc. of the Hampshires are in keeping with the findings of Schott *et al.* (1938), who reported 2.5 services necessary to produce pregnancy in Hampshires, while 2.9 were necessary with Shropshires. No good comparison could be made of percentage of abnormal sperm with the 1942 rams, since there was a very great individual difference. The three good rams in the 1942 group averaged 5.6 percent of abnormal sperm, which does not appear to differ significantly from the 8.3 percent of the untreated groups of the present experiment.

Summary and Conclusions

Comparison was made between groups of rams fed 2 gm., 1 gm. and no thyroprotein in the daily ration for a period of 15 weeks from late May to early September, 1946.

In each treatment group there were represented a mature ram and a yearling each of the Hampshire and Shropshire breeds.

Observations were taken on semen volume, concentration (million sperm per cc.), percentage of abnormal spermatozoa, motility score and growth of the rams during the test period.

Semen volume was significantly affected by age of the rams, yearlings of both breeds combined averaging 0.908 cc. and mature rams 0.626 cc.

Semen concentration was significantly affected by treatment, season and breed. The normally-fed lot produced more sperm per cc. than either treated group. There was a marked decline in million sperm per cc. from May to September, regardless of treatment, and Hampshires averaged more sperm per cc. than the Shropshires.

Percentage of abnormal sperm differed significantly owing to treatment and age of the rams. The highest percentage of abnormal sperm was in the group receiving 2 gm. of thyroprotein and in the older rams.

Motility score was affected by treatment, breed and age. The highest motility was in the untreated group and in yearlings and Hampshires.

Rate of growth of the rams was not affected by any of the variables (treatment, breed, age, season) considered.

Comparison was made with a normally-fed group of rams for a similar period in 1942. The seasonal and breed effects on semen concentration and motility score agreed for the 1942 and 1946 groups.

Some of the marked differences between the treated and untreated groups may have been due to individual variation of the rams. This could also account for some of the breed and age differences.

The results of this experiment do not indicate that the feeding of thyroprotein to rams was beneficial, since neither fed group was as good as the unfed group in semen concentration, percentage of normal sperm and motility score. However, the volume of ejaculate was somewhat higher in the lot fed 2 gm. of thyroprotein than in the other 2 groups.

Literature Cited

Bogart, Ralph and Dennis T. Mayer. 1946. The Relation of Temperature and the Thyroid to Mammalian Reproductive Physiology Am. Jour. Physiol. 147: 320–328.

Bogart, Ralph and Dennis T. Mayer. 1946a. Environmental Temperature and Thyroid Gland Involvement in Lowered Fertility of Rams. Mo. Agric. Expt. Sta. Res. Bul. 402.

Knoop, C. E. 1946. The Effect of Feeding Potassium Iodide and Skim Milk Powder on Spermatogenesis. (Abstract). Jour. Dairy Sci. 29(8): 555.

McKenzie, Fred F. and Victor Berliner. 1937. The Reproductive Capacity of Rams. Mo. Agric. Expt. Sta. Res. Bul. 265.

Phillips, Ralph W., Ralph G. Schott, Orson N. Eaton and Victor L. Simmons. 1943. Seasonal Variation in the Semen of Sheep and Goats, Cornell Vet. 33: 227–235.

Reineke, E. P. 1946. The Effect of Synthetic Thyroprotein on Sterilty in Bulls. "The Problem

of Fertility" Proc. on Conf. on Fertility, pp. 233–242. Princeton Univ. Press, Princeton, N. J.

Schott, R. G., E. M. Gildow and R. W. Phillips. 1938. Problems in Long-range Insemination of Livestock. Am. Soc. An. Prod., Proc., pp. 241–246.

Schultze, A. B. and H. P. Davis. 1946. The Influence of Feeding Synthetic Thyroprotein on Fertility of Bulls.

Turner, C. W., J. P. Mixner and E. P. Reineke. 1943. Thyroprotein for Sterile Goats. Dairy Goat Jour. 21: 1, 21.

COMPARISON OF CORRIEDALE × NAVAJO AND ROMNEY × NAVAJO CROSSES[1]

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Introduction

THE semi-arid conditions of the Navajo Indian Reservation are rather typical of large areas of the southwest. Sparcity of range feed and the lack of adequate stock water are factors which limit the productiveness of sheep in this region of the country. The sheep must be able to subsist under adverse conditions and to travel long distances for feed and water, especially in periods of severe drought. Thus adaptability of the sheep is a highly important factor in determining economic returns from wool and lamb production.

The old-type Navajo sheep are extremely hardy and well adapted to the environmental conditions of this area. As Cooper (1939) and Blunn (1943) have pointed out, the Navajo sheep have had about 400 years in which to become adapted to the region. Navajo sheep also possess other desirable traits. The ewes are prolific and long lived. They have a highly developed maternal instinct and are excellent milk producers, which enable them to raise a high percentage of their lambs under adverse conditions. Navajo sheep, however, are deficient in some important economic traits. In common with native sheep in other parts of the world, the Navajo sheep lack desirable mutton type and produce light fleeces of wool containing a mixture of hair, kemp, and other medullated fibers. This type of wool is satisfactory for making Navajo rugs but has a low commercial value.

In recent years the old-type Navajo sheep have practically disappeared as a result of the grading-up of Navajo flocks with purebred rams, principally of the Rambouillet breed. Through this process of sheep improvement, the advantages inherent in Navajo sheep with respect to adaptability, longevity of life, fecundity, and maternal characteristics have been largely lost. Moreover the resulting type of wool is unsatisfactory for Navajo hand weaving.

There is need for a breed of sheep that will not only possess a high degree

[1] This study was conducted under authority of the Bankhead-Jones Act, by the Bureau of Animal Industry, U. S. Department of Agriculture, in cooperation with the Office of Indian Affairs, U. S. Department of the Interior, at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico.

[2] U. S. Department of the Interior, and collaborating with the U. S. Department of Agriculture. The assistance of Harold W. Wolf, formerly with the U. S. Department of Agriculture, now at the Forstman Woolen Company, Passaic, New Jersey, is acknowledged.

of adaptability to southwestern range conditions, but also yield the maximum income from wool and lambs that is possible under existing conditions in this area. To meet the requirements of Navajo Indians the wool should be suitable for hand weaving and have a market value equal to that of other wools of similar fineness.

In 1935 and 1936 a foundation flock of about 800 old-type Navajo sheep was assembled at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, for experimental breeding. Some of these ewes were used for crossbreeding with purebred rams of the Corriedale and Romney breeds. The object of this study is to compare the lamb production of Corriedale × Navajo and Romney × Navajo crosses, to evaluate data on various characteristics of yearling ewes of these crosses, and to examine their suitability for foundation sheep in the development of a new breed suited to the requirements of sheepmen in this area.

Materials and Methods

Lamb production records for a total of 817 matings of old-type Navajo ewes with purebred Corriedale and Romney rams during the years 1937 to 1942 were studied. Production records for 71 half-blood Navajo ewes and 17 three-fourths blood Navajo ewes backcrossed to Romney rams are included in the summary for the Romney x Navajo cross. Data on 283 yearling crossbred daughters and their dams are also presented.

A total of 6 Corriedale and 6 Romney rams were used during the 6-year period. One ram of each breed was used 3 of the 6 years, each of 2 Corriedale and 3 Romney rams were used 2 of the 6 years, and each of 3 Corriedale and 2 Romney rams were used 1 year. Four of the Corriedale rams had fleeces grading three-eighths blood and two graded quarter blood in fineness, while the fleeces of 5 Romney rams graded quarter blood and 1 graded low quarter blood. In the selection of these rams special attention was given to the quality of their fleeces as indicated by uniformity in fiber diameter and relative freedom from medullated fibers. In all other respects the rams were good specimens of their respective breeds.

The original Navajo ewes were of mixed ages, and unfortunately many of those available for crossbreeding in 1936 and 1937 were somewhat below average with respect to body size, fleece quality, and fleece weight. Also, their fleeces were finer than the average, and showed evidence of some Rambouillet blood. During the last 4 years (1938–41), the quality of ewes available for crossbreeding was improved by the addition of selected young Navajo ewes produced in the breeding program at Fort Wingate, New Mexico. Ewes used for 2 or more years were alternated between rams of the Corriedale and Romney breeds, and additional ewes were allotted at random.

All ewes bred to Corriedale and Romney rams were grazed in the same flock, and therefore subject to the same management and environment.

Breeding started early in December and continued for a period of 30 days. The ewes were pen bred but grazed on the range during the day. Each day, about 4 o'clock P.M., the herd was brought into a centrally located corral, and ewes showing signs of estrus were sorted out by means of teaser rams, then placed in pens overnight with rams to which they had been previously assigned. During the breeding season and until green feed became available about May 1, the ewes received a supplemental ration of about ¼ pound of cottonseed cake per head daily.

Lambs were herded with their dams on the range near Fort Wingate until weaned. Individual body weights (weaning weights) were taken when the lambs of each cross were at an average age of about 140 days, and the unadjusted weights were used in this study. The ewe lambs, after being weaned, were grazed with the breeding flock and received cottonseed cake during the winter months, as outlined for the ewes.

Each year, just prior to shearing, the fleeces of all yearling ewes were sampled from the middle of the left side for laboratory determination of various physical properties. The staple length was measured to the nearest 0.1 centimeter on the sheared locks. Average fiber diameter was obtained by measurement of the cross-sections of 100 individual fibers from each sample, using the method described by Grandstaff and Hodde (1940). The percentages of kemp and other medullated fibers were determined by count from the magnified cross-sections as reported by Grandstaff (1941). Fleece weight to the nearest 0.05 pound and body weight to the nearest pound after shearing were taken at the time the sheep were shorn, about June 1. Clean fleece weights were obtained by scouring small side samples and multiplying the percentage of the bone dry yields of these samples by the grease fleece weights. The clean fleece weights can be adjusted to a commercial basis with 12 percent moisture content by dividing by 0.88.

Body weights and grease fleece weights for the dams were obtained each year at shearing time during their lifetime in the flock. Fleece samples collected from side of each ewe just prior to time of first shearing were evaluated for fineness and percentages of kemp and other medulated fibers by the methods outlined for yearling ewes.

Results and Discussion

Lamb production of Navajo ewes bred to Corriedale and Romney rams for the years 1937 to 1942 is summarized in table 1. Mean differences between crosses, for weaning weights and pounds of lamb produced per ewe bred, are given in table 2.

TABLE 1. LAMB PRODUCTION WITHIN YEARS OF NAVAJO EWES BRED TO CORRIEDALE AND ROMNEY RAMS

Breed cross	Year	Rams[1] used	Ewes bred	Ewes lambing	Lambs born of lambing ewes	Lambs weaned of ewes bred	Lambs weaned of live lambs born	Weaning weight	Lamb weaned per ewe bred
		number	*number*	*percent*	*percent*	*percent*	*percent*	*pounds*	*pounds*
Corriedale ×Navajo	1937	1	39	84.6	127.3	94.9	88.1	50.46	45.28
	1938	1	38	81.6	148.4	113.2	93.5	56.39	63.82
	1939	2	71	97.2	121.7	104.2	90.2	57.34	59.76
	1940	1	50	90.0	124.4	100.0	89.3	55.84	55.84
	1941	4	210	85.7	146.7	117.1	93.2	66.77	78.21
	1942	1	51	100.0	145.1	127.5	87.8	58.97	75.16
	Total or average	6	459	89.1	138.4	112.2	91.5	61.37	68.59
Romney ×Navajo	1937	1	36	88.9	121.9	75.0	75.0	55.11	41.33
	1938	1	39	84.6	124.2	84.6	82.5	57.09	48.31
	1939	2	69	89.8	127.4	98.6	86.1	56.79	55.97
	1940	4	163	90.2	126.5	93.9	84.5	53.04	48.78
	1941	2	88	83.0	117.8	79.5	84.3	71.10	56.56
	1942	1	51	96.1	159.2	119.6	78.2	54.24	66.08
	Total or average	6	446	88.8	128.5	92.4	83.1	57.51	53.38

[1] Some rams used more than one year, see narrative.

The Corriedale matings resulted in an average of 89.1 percent of pregnant ewes compared with 88.8 percent for the Romney matings. The Corriedale cross was superior to the Romney cross in prolificacy, and in livability and rate of growth of the lambs. The advantage of the Corriedale cross over the Romney cross, in percentage of lambs born of ewes lambing, percentage of lambs weaned of live lambs born, and percentage of lambs weaned of ewes bred was 9.9, 8.4, and 19.8 percent respectively. The higher percentage of lambs weaned by the Corriedale cross plus some advantage in weaning

TABLE 2. MEAN DIFFERENCES BETWEEN CROSSES FOR WEANING WEIGHTS OF LAMBS AND POUNDS OF LAMB WEANED PER EWE BRED

Characteristic	Corriedale cross minus romney cross for years shown						
	1937	1938	1939	1940	1941	1942	6-year mean
Weaning weight, pounds	−4.65*	− 0.70	+0.55	+2.80**	− 4.33**	+3.73**	+ 3.86**
Lamb weaned per ewe bred, pounds	+3.95**	+15.51**	+3.79	+7.06*	+21.65**	+9.08*	+15.21**

* Signifies probability of chance occurrence <.05.
** Signifies probability of chance occurrence <.01.

weight of lambs resulted in rather large differences between crosses in the weight of lamb produced per ewe bred, as shown later.

Average weaning weights of lambs sired by the Corriedale and Romney rams during the 6-year period were 61.37 pounds and 57.51 pounds, respectively. The mean difference of 3.86 pounds was highly significant. The Romney crossbred lambs were heavier at weaning age in 1937, 1938, and 1941, while the Corriedale crossbreds were heavier in 1939, 1940, and 1942. The mean yearly differences between crosses were significant for 1937 and highly significant for 1940, 1941, and 1942. In 1941 weaning weights of both crosses were well above the average of other years, as a result of highly favorable environmental conditions. The total precipitation in 1941 of 18.47 inches was 67 percent above the average of the other four years (1938, 1939, 1940, and 1942) for which records are available, and 28 percent above the 47-year (1864–1911) average at Fort Wingate, New Mexico.

Total weight of lamb weaned per ewe bred during the 6-year period averaged 68.59 pounds and 53.38 pounds for the Corriedale and Romney crosses, respectively. The mean difference of 15.21 pounds was highly significant. Moreover the Corriedale cross ranked first in each of the 6 years, the mean differences ranging from 3.79 in 1939 to 21.65 pounds in 1941. Mean differences between crosses for the years 1940 and 1942 were significant and for 1937, 1938, and 1941 the differences were highly significant. The rather

consistent superiority of the Corriedale cross, in lamb production, was derived partly from greater prolificacy but mainly from better adaptability to southwestern range conditions. The Corriedale breed is found in widely separated sections of the United States, including the southwestern states, whereas the Romney breed is confined quite largely to the farms of the Pacific coast states.

In evaluating the performance of Corriedale × Navajo and Romney × Navajo crosses, it is of interest to compare the lamb production of these crosses with that of Navajo ewes bred to Navajo rams. Data on a total of 1947 matings of Navajo ewes and rams during the 6 years from 1937 to 1942, show an average of 88.6 percent of ewes lambing, which is comparable to the figures reported for the Corriedale and Romney crosses. Percentage of lambs born of ewes lambing, percentage of lambs weaned of ewes bred, and percentage of lambs weaned of live lambs born were 127.3, 99.5, and 92.3 respectively. Navajo lambs exceeded the Corriedale and Romney crossbreds in livability, but the percentage of Navajo lambs reared was between the values obtained for the two crosses. Average weaning weight and pounds of lamb weaned per ewe bred for the Navajo strain were approximately 57.0 pounds, which compares with the values for the Romney cross, but are significantly lower than the values observed for the Corriedale cross.

Yearly differences in weaning weights of Navajo lambs were less than those observed for the crossbred lambs, indicating that they respond differently to changes in environmental conditions. When feed conditions are average or below average, the Navajo and crossbred lambs tended to have a similar rate of gain, but when feed conditions were abnormally good as in 1941, both crosses definitely exceeded the Navajo lambs in rate of gain (Blunn, 1945).

A total of 173 Corriedale F_1 ewe lambs and 110 Romney crossbred ewe lambs were saved for future breeding use, which represented 33.6 percent and 26.7 percent, respectively, of the total numbers of lambs (male and female) raised to weaning age. The percentage of lambs culled was significantly higher for the Romney cross than it was for the Corriedale cross.

Mean yearling values for seven different characteristics of the Corriedale and Romney crossbred ewes are summarized in table 3, and results of the analysis of variance on these data are given in table 4.

Average body weights for the Corriedale and Romney crosses were 98.10 pounds and 96.69 pounds, respectively. The mean difference of 1.41 pounds was not significant. The Romney crossbreds had slightly longer staple than the Corriedale F_1's, but the mean difference of 0.34 centimeter was not significant. The Corriedale F_1 ewes sheared heavier fleeces which yielded more clean wool, although they had a higher shrinkage than the

TABLE 3. MEAN VALUES FOR VARIOUS YEARLING CHARACTERISTICS OF CORRIEDALE×NAVAJO AND ROMNEY×NAVAJO EWES

Breed cross	Year born	Ewes	Body weight	Grease fleece weight	Clean fleece weight	Staple length	Fiber diameter	Kemp fibers	Other medullated fibers
		number	*pounds*	*pounds*	*pounds*	*centimeters*	*microns*	*percent*	*percent*
Corriedale ×Navajo	1937	19	89.47	5.28	2.58	15.15	22.96	0.26	2.47
	1938	10	90.60	5.24	2.99	7.84	26.20	0.98	3.34
	1939	24	91.75	5.93	3.45	13.84	26.21	0.82	6.47
	1940	18	102.56	7.27	4.38	11.34	26.55	0.51	8.88
	1941	87	99.80	7.40	3.78	8.46	26.68	0.18	3.98
	1942	15	109.13	8.10	4.78	8.48	25.11	0.00	2.95
	Total or average	173	98.10	6.88	3.71	10.20	26.02	0.34	4.59
Romney ×Navajo	1937	13	93.54	4.86	2.21	12.85	23.30	0.92	2.19
	1938	12	88.08	4.84	2.67	10.46	26.77	1.71	11.83
	1939	14	89.36	3.98	2.69	14.68	27.99	1.05	7.17
	1940	39	100.64	6.39	3.62	9.93	27.17	0.96	6.39
	1941	22	98.14	7.27	3.85	8.09	26.72	0.64	3.78
	1942	10	102.80	7.29	4.58	9.63	28.83	0.21	5.51
	Total or average	110	96.69	5.99	3.36	10.54	26.84	0.92	6.15

TABLE 4. SUMMARY OF ANALYSIS OF VARIANCE FOR EACH OF SEVEN CHARACTERISTICS OF YEARLING CORRIEDALE ×NAVAJO AND ROMNEY×NAVAJO EWES
(mean squares only)

Source of variation	Degrees of freedom	Body weight	Grease fleece weight	Clean fleece weight	Staple length	Fiber diameter	Kemp fibers	Other medullated fibers
Total	282	186	2.72	0.98	14.61	5.62	1.44	25.67
Years	5	1553**	41.03**	20.38**	304.93**	77.22**	7.80**	175.56**
Crosses	1	136	53.35**	7.92**	7.68	43.83**	21.25**	157.73**
Error	276	161	1.84	0.60	9.38	4.19	1.25	22.34

** Signifies probability of chance occurrence <.01.

fleeces of the Romney crossbreds. Mean differences in grease and clean fleece weights of 0.89 pound and 0.35 pound were highly significant. The average fiber diameter for ewes of each cross was equal to that of grade 58s. The fleeces of the Romney crossbreds however, averaged 0.82 micron coarser, had 0.58 per cent more kemp, and 1.56 percent more of other medullated fibers than the fleeces of the Corriedale F_1 ewes. The mean differences in fiber diameter and in percentages of kemp and other medullated fibers were highly significant.

The variance due to differences between the means of years was highly significant for all the characteristics studied. Differences between crosses represented a highly significant source of variance for all characteristics except yearling body weight and staple length.

Mean values for various characteristics of the dams of the yearling crossbred ewes and a summary of the analysis of variance of these data are presented in table 5 and 6. There was no significant difference between the two lots of ewes in any characteristic except average fiber diameter. Ewes bred to Corriedale rams had an average fiber diameter of 26.53 microns compared with 25.45 microns for the Romney bred ewes. The difference of 1.08 microns was highly significant. If the two groups of ewes had been equal in fiber fineness, the mean difference between their yearling progeny would probably have been greater than the 0.82 micron observed.

The variance resulting from yearly differences was highly significant for all characteristics of the Navajo ewes including average life-time body weight, average lifetime grease fleece weight, average fiber diameter, and percentages of kemp and other medullated fibers. Large variations were due to the fact that different ewes were assigned to rams each year and the Navajo ewes were not a fixed type, thus lacking uniformity in all characteristics.

Since the Navajo sheep were an unimproved type, the Corriedale and

TABLE 5. MEAN VALUES FOR VARIOUS CHARACTERISTICS OF DAMS OF YEARLING CORRIEDALE×NAVAJO AND ROMNEY×NAVAJO EWES

Breeding group	Year of lambing	No. of ewes	Body weight	Grease fleece weight	Fiber diameter	Kemp fibers	Other medullated fibers
			pounds	*pounds*	*microns*	*percent*	*percent*
Corriedale Cross	1937	19	84.68	4.10	25.91	0.45	7.05
	1938	10	92.80	4.04	25.89	0.92	5.89
	1939	24	93.96	4.45	26.32	1.76	6.00
	1940	18	94.28	4.94	26.93	3.69	8.19
	1941	87	96.51	4.97	26.64	1.39	6.89
	1942	15	102.20	5.15	26.76	0.81	4.49
	Total or average	173	94.90	4.76	26.53	1.38	6.66
Romney Cross	1937	13	87.69	4.03	25.24	0.10	1.49
	1938	12	86.75	3.59	22.59	1.66	5.74
	1939	14	90.21	3.82	26.71	1.75	7.23
	1940	39	94.51	4.85	25.74	1.83	6.71
	1941	22	102.73	6.39	26.28	0.97	8.17
	1942	10	97.60	4.84	24.84	1.23	3.29
	Total or average	110	93.96	4.79	25.45	1.37	6.07

Romney crossbreds would be expected to show improvement in mutton and fleece qualities, and in body and fleece weights. Comparing the mean values for the yearling crossbred ewes and their dams, tables 3 and 5, it is found that the daughters showed considerable improvement over their dams in several important characteristics. In making these comparisons, however, it should be remembered that body and fleece weights of the dams are lifetime averages, based on total years on the flock, whereas data for the daughters represent yearling values. Differences between the mean body and fleece weights of dams and daughters would probably be somewhat greater if adjusted to a comparable age basis. The crossbred ewes would not reach mature body weight until about 2½ years of age, and maximum wool production until 3 years of age. The effect of hybrid vigor in the first cross was not quite as great as expected. In body weight, the yearling daughters averaged 2 to 3 pounds heavier than their dams, and substantial improvement in body type and mutton qualities was observed. Grease fleece weights showed an increase of from 25 percent for the Romney cross to about 47 percent for the Corriedale cross.

The Corriedale cross was more effective than the Romney cross in improving fleece quality through reduction in the quantities of kemp and other medullated fibers. On the other hand, the Romney cross produced more desirable results with respect to fineness of the wool. The Romney crossbreds

TABLE 6. SUMMARY OF ANALYSIS OF VARIANCE FOR EACH OF FIVE CHARACTERISTICS OF DAMS OF YEARLING CORRIEDALE ×NAVAJO AND ROMNEY×NAVAJO EWES
(mean squares only)

Source of variation	Degrees of freedom	Body weight	Grease fleece weight	Fiber diameter	Kemp fibers	Other medullated fibers
Total	282	109	1.55	7.09	2.67	20.80
Years	5	1012**	15.41**	14.79**	34.82**	63.10**
Groups	1	29	0.06	10.94**	0.01	23.66
Error	276	93	1.31	6.70	2.10	20.01

** Signifies probability of chance occurrence <0.01.

averaged 1.39 microns coarser in average fiber diameter than their dams, whereas the progeny of Corriedale rams averaged 0.51 micron finer in fiber diameter than their dams. From the standpoint of hand weaving however, the fleeces of a high percentage of the progeny of both crosses were too fine. Wool of a more satisfactory quality for hand weaving might be obtained by crossbreeding with rams of some of the coarser wooled breeds such as the Lincoln, Leicester, or Cotswold.

Summary

At the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, old-type Navajo ewes were mated to purebred Corriedale and Romney rams, and some one-half and three-fourths blood Navajo ewes were backcrossed to Romney rams. Six rams of each breed were used, the period of service for individual rams varying from 1 to 3 years. Data on lamb production for a total of 905 matings during the years 1937 to 1942 were studied. These matings resulted in an average of 89 percent of pregnant ewes for each cross. The Corriedale cross excelled in percentages of lambs born and reared, and in rate of growth of lambs from birth to weaning age. Mean differences in average weaning weights of lambs, and in pounds of lamb produced per ewe bred, of 3.86 pounds and 15.21 pounds, respectively, were highly significant.

A total of 283 ewe lambs, including 173 of the Corriedale cross and 110 of the Romney cross, were saved as breeding prospects. The percentage of lambs culled was significantly greater for the Romney than for the Corriedale cross.

At yearling age there was no significant difference between the Corriedale and Romney crossbred ewes, in body weight or staple length. The ewes sired by Romney rams had coarser fleeces containing higher percentages of kemp and other medullated fibers, but the Corriedale F_1 ewes ex-

celled in fleece weight on both grease and clean basis. Differences between crosses with respect to grease fleece weight, clean fleece weight, fiber diameter, and percentages of kemp and other medullated fibers, were highly significant. The Romney cross produced greatest improvement with respect to hand weaving properties of the wool, but the fleeces from a high percentage of both the Corriedale and Romney crossbreds was from one to two grades finer than the most desired type.

Data on five characteristics of the dams of the yearling crossbred ewes are also presented, and improvement of daughters over dams is discussed.

Literature Cited

Blunn, Cecil T. 1943. Characteristics and Production of Old-Type Navajo Sheep, Jour. Heredity 34: 141–152.

Blunn, Cecil T. 1945. Yearly Differences in Growth of Navajo and Crossbred Ewe Lambs. JOURNAL OF ANIMAL SCIENCE 4: 306–310.

Cooper, J. M. 1939. Breeding for Adaptability to Local Conditions, With Special Reference to Sheep on the Navajo Indian Reservation, Am. Soc. An. Prod., Proc., pp. 26–32.

Grandstaff, James O. and Walter L. Hodde. 194c. A Rapid Method for Projecting and Measuring Cross Sections of Wool Fibers, U. S. Dept. of Agric. Circ. 590, 11 pp., illus.

Grandstaff, James O. 1941. Evaluating Fleece Characteristics of Navajo Sheep From a Breeding Standpoint. Rayon Textile Monthly 22: 599–601, 664–666.

THE EFFECT OF HEMOPOIETIC DIETARY FACTORS ON THE RESISTANCE OF LAMBS TO PARASITISM WITH THE STOMACH WORM, *HAEMONCHUS CONTORTUS*[1]

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ANEMIA is one of the symptoms associated with internal parasitism in sheep. Fourie (1932) and Andrews (1942) have demonstrated that this anemia is primarily due to a loss of blood, as both of these workers have been able to produce a similar anemia by bleeding the host animal.

The relationship of nutrition to parasite resistance has been the subject of many studies with several species of parasites and various types of host animals. Foster and Cort (1931, 1932, 1935) found that dogs fed a good diet were resistant to reinfection with the hookworm, *Ancylostoma caninum*, while the same dogs when fed a poor diet were very susceptible to reinfection. Taylor (1943) demonstrated that lambs receiving a full ration of hay and concentrates contained fewer worms at autopsy than did lambs fed a ration of hay only.

Stewart (1933) reported that when a group of sheep infected with hookworm was fed a ration high in protein and mineral, these sheep became free of hookworms while the low protein and the mineral fed groups remained infected.

Ackert (1942) in his review concluded that when omnivorous hosts are maintained on diets deficient in vitamins A, B-complex, or D, or on a ration with highly restricted sources of proteins, the natural resistance to helminthic infections was lowered.

Foster and Landsberg (1934) suggested that iron, copper, and cobalt were of value in aiding dogs to withstand hookworm infections.

Preliminary field trials in Wisconsin (Pope *et al.*, 1947) showed that feeding trace-mineralized salt containing cobalt, copper, iron, manganese, and iodine to sheep flocks, reduced death losses. In an effort to explain these results a study of the relationship of the nutrition of the sheep and the effects of internal parasites was undertaken and in part is reported herewith.

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Experimental Procedures and Results

In 1946 12 ewes and in 1947 32 aged Shropshire-Oxford ewes were used to produce parasite-free lambs. These ewes were fed the rations shown in table 1. The hay used was of poor to medium quality as purchased at random by the University Farm Office. Lambs were fed the ewe grain mixture free choice in a creep, and had access to the ewes' salt mixture.

The ewes lambed in April. The lamb production record of these ewes is shown in table 2. In 1946 each ewe raised one lamb. The lambs from lots 3 and 4 where the ewes were receiving the additional protein and energy in the form of soybean oil meal, were considerably heavier at 60 days of age. In 1947, however, considerable mortality occurred in the non-mineral lots 1 and 3, and the lambs from these lots did not grow as well as the lambs from the mineral lots. These data seem to point to a mineral deficiency. The lamb

TABLE 1. RATIONS FED EXPERIMENTAL EWES*

Lot No.	Ration	Amounts fed	
		Before lambing	After lambing
1	*Basal*		
	Mixed grass-legume hay (poor to medium quality)	4.0 lb.	4.0 lb.
	Gr. yellow corn	0.25 lb.	0.50 lb.
	Iodized salt	Free choice	Free choice
2	*Basal+minerals*		
	Mixed grass-legume hay (poor to medium quality)	4.0 lb.	4.0 lb.
	Gr. yellow corn with 1% steamed bone meal	0.25 lb.	0.50 lb.
	Trace-mineralized salt**	Free choice	Free choice
3	*Basal+protein*		
	Mixed grass-legume hay (poor to medium quality)	4.0 lb.	4.0 lb.
	Gr. yellow corn	0.25 lb.	0.75 lb.
	Soybean oil meal	0.25 lb.	0.25 lb.
	Iodized salt	Free choice	Free choice
4	*Basal+protein+minerals*		
	Mixed grass-legume hay (poor to medium quality)	4.0 lb.	4.0 lb.
	Gr. yellow corn with 1% steamed bone meal	0.25 lb.	0.75 lb.
	Soybean oil meal	0.25 lb.	0.25 lb.
	Trace-mineralized salt	Free choice	Free choice

* Lambs fed ewe grain mixture free choice in the creep. Access to ewe salt mixture.

** Trace-mineralized salt—the following added to 100 lb. salt:

200 gm. Fe_2O_3
100 gm. $MnSO_4.H_2O$
100 gm. $CuSO_4$
10 gm. $CoSO_4.7H_2O$
10 gm. KI plus stabilizer

TABLE 2. LAMB PERFORMANCE RECORD

Year and lot	No. of ewes	No. of lambs born	No. of lambs alive at 60 days	Mortality	Av. wt. of lambs at 60 days		Pounds of lamb per cwt. ewe at 60 days	
					Singles	Twins	Singles	Twins
				percent	lb.	lb.	lb.	lb.
1946: 1	3	3	3	0	36.3		31.2	
2	3	4	3	25.0	37.3		32.0	
3	3	3	3	0	45.1		35.2	
4	3	3	3	0	45.3		38.2	
1947: 1	7	8	5	37.5	37.2		21.9	
2	8	11	11	0	40.5 (5)*	30.0 (6)	34.3	41.4
3	7	8	6	25.0	38.6		26.7	
4	7	10	10	0	44.8 (4)	34.1 (6)	33.6	49.5

*( ) number of individuals averaged.

feed consumption data likewise suggest that the 1947 lambs were deficient in some dietary essential. In 1946 the average daily grain consumption per lamb from May 10 to November 5 was .58, .42, .73, and .77 pound in lots 1, 2, 3, and 4 respectively, while in 1947 the grain consumption from April 29 to October 13 was .66, 1.05, .79, and 1.17 pound for lots 1, 2, 3, and 4 respectively.

In the 1947 experiment, 4 single lambs from lots 1 and 3, and 4 single and 4 twin lambs from lots 2 and 4 were selected for parasite infection tests. These lambs were uniform in age and thrifty in appearance. The selected lambs were paired on the basis of weight and age for both the infected and the control groups.

The infected lambs were given approximately 4,000 infective larvae of *Haemonchus contortus* on July 14. On August 26 these same lambs were given about 15,000 more larvae.

The effect of the parasite infections on the growth of these lambs is shown in table 3. The lot 4 lambs receiving minerals and the higher level of protein made the best gains, followed by the lot 2 lambs fed minerals and the lower level of protein. Both the uninfected and infected lambs on the basal ration made poor gains. The infected lamb which died in lot 3 was found to have a streptococcic encephalitis. This death loss is not believed to have been due to the parasites.

Hemoglobin of the lambs was determined weekly by the oxyhemoglobin method. Table 4 shows the average hemoglobin values for the lambs at 3 of these bleedings. Throughout the course of the experiment the lots 3 and 4 lambs on the higher level of protein maintained higher hemoglobin levels

TABLE 3. AVERAGE BODY WEIGHT OF LAMBS—1947

Lot no. and treatment	Initial no. of lambs	July 10	Aug. 29	Oct. 13	Gain after infection
		lb.	lb.	lb.	lb.
1: Infected[1]	2	47.5	60.0	69.0	21.5
Control	2	51.5	61.5	73.0	21.5
2: Infected[1]	4	46.0	61.8	79.5	33.5
Control	4	45.8	62.5	82.5	34.7
3: Infected[1]	2	49.0	67.0	80.0*	31.0
Control	2	52.0	68.5	79.5	27.5
4: Infected[1]	4	52.0	71.0	91.0	39.0
Control	4	52.5	74.0	92.5	40.0

* One lamb died.
[1] 4,000 larvae given July 14; 15,000 larvae given August 26.

than did the lots 1 and 2 lambs receiving less protein. There was no difference in the hemoglobin levels between lots 3 and 4 or between lots 1 and 2 receiving the same rations either without and with the minerals added to the ration.

The course of the parasite infection was followed by egg counts of the feces of the lambs. Detail egg count data will be reported elsewhere. All the lambs that received mineral supplements passed eggs in their feces by

TABLE 4. AVERAGE HEMOGLOBIN VALUES OF LAMBS, 1947, GM./100 ML. BLOOD

Lot no.	Initial no. of lambs	July 14	Aug. 26	Oct. 6
1: Infected[1]	2	8.64	9.59	8.51
Control	2	7.99	10.42	9.78
2: Infected[1]	4	8.37	9.61	7.77
Control	4	9.19	10.23	10.50
3: Infected[1]	2	10.73	11.89	9.34*
Control	2	9.09	11.05	10.50
4: Infected[1]	4	9.00	10.61	9.84
Control	4	9.78	11.90	11.84

* One lamb died.
[1] 4,000 larvae given July 14; 8 15,000 larvae given August 26.

August 1, that is, 17 days after receiving the larvae. The lambs without minerals passed eggs uniformly later than those which received minerals. One lamb in lot 1 began passing eggs 21 days after infection, and the other lamb 23 days after infection. The lot 3 lambs on the higher protein-low mineral ration did not begin to pass eggs until 25 days after receiving the larvae.

In order to determine the actual number of worms carried by these lambs, all lambs were killed on October 15. The post-mortem worm counts showed an average of 768, 1,537, 1,152 and 1,442 worms per lamb for lots 1, 2, 3, and 4 respectively. Although there was considerable individual variation within lots, the average number of worms found in the lambs from the mineral lots 2 and 4 was clearly higher than the number found in the lambs from non-mineral lots 1 and 3. The highest number of worms found in any of the control lambs was 4 worms.

Blood samples from these lambs were analyzed for plasma vitamin C by the method of Mindlin and Butler (1938); for plasma vitamin A by the method of Kimble (1939); for plasma inorganic phosphorus by the method of Fiske and Subbarow (1925); and for total plasma protein by a semi-micro-chemical Kjeldahl determination.

The blood plasma vitamin C values showed a downward trend after the infection in most cases, but the controls also decreased in several instances. The blood plasma vitamin A also decreased during the course of the infection in a majority of the lambs, but the effect was not consistent. Little difference was detected in the plasma inorganic phosphorus values between the infected and control lambs. In all lots the control lambs maintained higher blood plasma protein levels than did the infected lambs. No significant differences were obtained between lots for any of these blood constituents.

In 1946 only 3 lambs were available in each lot for the parasite tests. On June 20 the medium weight lamb in each lot was given 4,000 infective larvae and on August 1 given 45,000 additional larvae. The effect of these larger infections of larvae on the growth of the lambs is shown in section 1 of table 5. The lot 2 lamb receiving the basal ration plus minerals continued to gain after the first infection but died a month after receiving the large infection of larvae. The basal ration lamb failed to gain after the initial infection and died 4 weeks after the large infection. Worm counts were made on these 2 lambs upon autopsy. The lots 3 and 4 lambs receiving the higher level of protein continued to gain despite the parasite infections.

The hemoglobin values given in section 1, table 6, show that the lambs in lots 1 and 2 became very anemic before dying, following the 45,000 larvae infection. The lot 3 lamb's hemoglobin level declined but remained in the normal range and much higher than that of the lot 4 lamb. The lot 4 lamb on the higher level of protein and minerals was anemic but continued to gain.

In this test the lambs from the mineral lots 2 and 4 began passing eggs

TABLE 5. BODY WEIGHT OF LAMBS, 1946

Section 1. Given 4,000 larvae June 20. Given 45,000 larvae August 1.

Lot no.	No. of lambs	June 20	Aug. 1	Sept. 30	Nov. 4
		lb.	lb.	lb.	lb.
1	1	35	38	Died 8/27	
2	1	39	55	Died 9/1	
3	1	48	67	82.5*	
4	1	51	69	86*	
Section 2. Given 45,000 larvae August 1					
1	1	42	63		70
2	1	39	60	Died 9/9	
3	1	55	80		99
4	1	54	76		65
Section 3. Controls					
1	1	33	54		64
2	1	34	50		64
3	1	40	52		50
4	1	42	61		94

* Sacrificed for worm count.

TABLE 6. HEMOGLOBIN OF LAMBS, 1946, GM./100 ML. BLOOD

Section 1. Given 4,000 larvae June 20. Given 45,000 larvae August 1.

Lot no.	No. of lambs	June 18	Aug. 1	Sept. 27	Nov. 4
1	1	10.35	6.72	(3.35—8/23; died 8/27)	
2	1	10.43	5.59	(2.84—8/29; died 9/1)	
3	1	10.09	12.56	9.41	
4	1	7.28	9.06	4.86	
Section 2. Given 45,000 larvae August 1					
1	1	8.54	11.37	5.60	6.34
2	1	12.41	11.55	(2.55—9/5; died 9/9)	
3	1	10.66	12.41	5.33	5.83
4	1	9.73	12.21	2.99	4.86
Section 3. Controls					
1	1	8.26	12.06	9.80	8.09
2	1	11.55	12.56	12.91	12.33
3	1	11.05	10.09	4.68	4.32
4	1	8.63	12.21	10.43	13.58

in their feces 21 days after receiving the second dosage of larvae on August 1. The lambs from the non-mineral lots began passing eggs 26 and 27 days after the infection. The lots 3 and 4 lambs were sacrificed for a worm count on September 30. The total number of worms found in these 4 lambs was 1,023; 6,686; 2,174; and 4,492 worms for the lambs from lots 1, 2, 3, and 4 respectively.

On August 1 the largest lamb in each lot was given a single dose of 45,000 infective larvae. The effect of this single large dose on the lambs is shown in section 2, table 5, and section 2, table 6. The lot 1 basal ration lamb survived the infection but gained little during the next 3 months. The lot 2 lamb receiving the same ration plus minerals died 5 weeks after receiving the larvae. The lot 3 lamb on the higher protein-low mineral ration continued to gain, while the lot 4 lamb on the higher protein-high mineral ration lost weight during the 3 months after receiving this large infection.

The hemoglobin of all these lambs dropped after the lambs received this heavy dose of larvae, the drop being most marked in the lambs receiving minerals in their ration.

The surviving lambs were sacrificed for worm count on November 4. The number of worms found was 1,804; 8,617; 4,098; and 5,000 for the lambs from lots 1, 2, 3, and 4 respectively. The count on the lot 4 lamb is an approximation as the jar was spilled when the worms were only partially counted.

This heavier infection with parasites in some cases appeared to have a depressing effect on the blood plasma ascorbic acid, but the relationship was not constant. The effect of the parasitic infection on the blood plasma vitamin A was not apparent. The lot 1 lamb which received the double infection was the only lamb which showed vitamin A and C levels in the deficient range. The blood plasma inorganic phosphorus level of all the infected lambs decreased after the infection.

Discussion of Results

These data are interpreted to mean that the addition of minerals to the ration makes conditions within the host animal more favorable for the establishment and development of the stomach worm *Haemonchus contortus*. Lambs which received the minerals in their rations in every test produced eggs in their feces 5 to 7 days earlier than did the lambs not receiving the minerals in their ration. In 1946 the largest number of worms in both tests was found in the lamb receiving the basal plus mineral ration. In 1947 the 4 lambs on this ration had the highest average number of worms. Lambs receiving the minerals and the higher level of protein contained the second highest number of worms.

When minerals were fed with protein (lot 4) smaller number of worms developed than in lot 2 where only minerals and the basal ration were fed. However, when protein alone was added to the basal ration in lot 3, larger numbers of worms were found. Thus the effect of protein on the parasite is not clear.

When the infection reached only moderately high levels as exemplified by the dose of 15,000 larvae, minerals in the ration appeared to aid the host in withstanding the parasitic infection, but when the infection became very high as when 45,000 larvae were given, the minerals seemed to help the parasite more than the host. The higher level of protein seemed to help the sheep to withstand the parasite infection with respect to hemoglobin values.

The poor growth of the control lambs on the basal ration indicates that the unsupplemented basal ration was incomplete for good growth even when the lambs were parasite-free. Somewhat better growth was obtained when the ration was supplemented with either protein or minerals. The best growth was obtained when this ration was supplemented with both protein and minerals. Whether the effect of the minerals is due to a specific element in the mineralized salt or the bone meal, awaits further investigation.

Summary and Conclusions

In order to study the relationship of nutrition to parasite infection in sheep, 4 lots of breeding ewes were used to produce parasite-free lambs during 1946 and 1947. These ewes were fed the following rations: 1—basal ration of mixed grass-legume hay and a small amount of corn; 2—basal ration plus trace-mineralized salt and bone meal; 3—basal ration plus soybean oil meal; 4—basal ration plus soybean oil meal, trace-mineralized salt, and bone meal.

The heaviest lambs were produced both years by the ewes receiving the basal ration supplemented with both protein and minerals. The ewes receiving the unsupplemented basal ration produced the smallest lambs both seasons.

When a group of these lambs was given an initial dose of 4,000 larvae of *Haemonchus contortus* and an additional dose of 15,000 larvae, the best gains were made by the lambs which were receiving the protein- and mineral-supplemented ration, followed by the lambs receiving the mineral, while poorer gains were made by the lambs not receiving the minerals.

When these lambs were given larger doses of 45,000 larvae, with and without a smaller initial dose of 4,000 larvae, 3 of the 4 lambs from the lower protein lots died within 6 weeks, and the lamb that lived gained little. All 4 of the lambs receiving the higher level of protein in the ration lived until

sacrificed for worm counts. Three of these 4 lambs continued to gain despite the parasite infection.

The hemoglobin levels of the lambs were depressed in all cases by the parasite infection. The higher level of protein in the ration aided the lambs in maintaining higher levels of hemoglobin. Other blood constituents—blood plasma vitamins A and C, inorganic phosphorus, and total plasma protein—were adversely affected in varying degrees by *Haemonchus contortus* infection.

Parasite eggs were detected in the feces of the lambs receiving minerals several days earlier after the infection with larvae than in lambs not receiving minerals in their rations. More worms were found in the abomasum of lambs which received minerals than in lambs that did not receive minerals in the ration.

Literature Cited

Ackert, J. E. 1942. Natural Resistance to Helminthic Infections. Jour. Parasitol. 28: 1–24.

Andrews, J. S. 1942. Stomach Worm (*Haemonchus contortus*) Infection in Lambs and Its Relation to Gastric Hemorrhage and General Pathology. Jour. Agric. Res. 65: 1–18.

Fiske, C. H. and Y. Subbarow. 1925. The Colorimetric Determination of Phosphorus. Jour. Biol. Chem. 66: 375–400.

Foster, A. O. and W. W. Cort. 1931. The Effect of Diet on Hookworm Infestation in Dogs. Science 73: 681–683.

Foster, A. O. and W. W. Cort. 1932. The Relation of Diet to Susceptibility of Dogs to *Ancylostoma caninum*. Amer. Jour. Hyg. 16: 241–265.

Foster, A. O. and W. W. Cort. 1935. Further Studies on the Resistance of Dogs to Hookworm Infestation. Amer. Jour. Hyg. 21: 302–318.

Foster, A. O. and J. W. Landsberg. 1934. The Nature and Cause of Hookworm Anemia. Amer. Jour. Hyg. 20: 259–290.

Fourie, P. J. J. 1932. The Haematology and Pathology of Haemonchosis in Sheep. Union So. Africa Dept. Agr. Div. Vet. Serv. and Anim. Indust. Ann. Rpt. 17: 495–572.

Kimble, M. S. 1939. The Photocolorimetric Determination of Vitamin A and Carotene in Human Plasma. Jour. Lab. and Clin. Med. 24: 1055–1065.

Mindlin, R. L. and A. M. Butler. 1938. The Determination of Ascorbic Acid in Plasma; a Macromethod and Micromethod. Jour. Biol. Chem. 122: 673–686.

Pope, A. L., P. H. Phillips, and G. Bohstedt. 1947. The Effect of Cobalt on Growth and Certain Blood Constituents of Sheep. JOURNAL OF ANIMAL SCIENCE 6: 334–342.

Taylor, E. L. 1943. The Interaction of Nutrition and Parasitism with Special Reference to Parasitic Gastritis. Vet. Rec. 55(10): 117–119.

THE EFFECT OF DIETARY FAT ON UTILIZATION OF THE ENERGY AND PROTEIN OF RATIONS BY SHEEP[1]

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CONSIDERABLE evidence has accumulated to indicate that dietary fat is of special nutritive significance on account of its associative effect on the utilization of energy of the ration as a whole.

Extensive investigation by Maynard and co-workers with dairy cows over a period of 15 years has indicated that the ration should contain a certain amount of fat for optimum milk production. Maynard and McCay (1929, 1932) found that a low fat dairy ration produced a marked decrease in milk volume with no change in the percentage of fat in the milk while rations in which fat was replaced with isodynamic amounts of starch produced milk fat of lower iodine number. Later work by Maynard, McCay, Williams and Madsen (1934) warranted the conclusion that a concentrate containing 4% fat is satisfactory if fed with good roughage and if supplied at the rate of 1 pound for every 3 to 3½ pounds of milk. Further work at the Cornell laboratories has confirmed the importance of fat in the dairy ration (Maynard, Gardner, and Hodson, 1939; Maynard, Loosli, and McCay, 1940; Maynard, Loosli and McCay, 1941). From work reported by Monroe and Krauss (1940) and by Lucas and Loosli (1944) it appears that not all aspects of the problem have been finally cleared up. No evidence has yet appeared, so far as the writers are aware, to indicate that a specific fatty acid or any particular component of the ether extract is responsible for these results.

Forbes and associates (1946*a*, *b*, *c*, *d*) have published results obtained from rapidly growing and from relatively mature rats using rations varying in fat content from 2 to 30 per cent. Economy of energy utilization increased in accord with the increase in fat content. Lard was used as the varying fat.

Similarly, Swift and associates (1947) found that an increase in digestibility of all constituents of a mixed ration occurred with sheep when the mixed ration was supplemented with corn oil, bringing the total ether extract up to 6.4 percent. When the amount of added corn oil was doubled, however, bringing the ether extract percentage of the ration to about 9.7%, the effect was just the reverse, the digestibility of all ration constituents being less than in the basal ration unsupplemented with corn oil. As a

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logical development of this observation, the present experiment was planned, the primary objective being to determine the optimum amount of fat in rations for sheep.

Materials and Methods

With the above objective in mind it was decided to determine the methane production and the energy metabolism of the sheep by the carbon-nitrogen balance method using the large respiration calorimeter at this institution. Although the calorimeter has always been used with individual animals only (cows or steers), it was felt that much of the individual variation could be eliminated by using four sheep in the chamber for each measurement instead of a single animal. Using the sheep in groups of four made possible the study of six rations by each of the four groups rather than the same number of rations by each of four single sheep during the same period of time. The quantities of carbon dioxide and methane obtained from a group of four sheep corresponded then more closely to the quantities of these gases which were obtained when a single, large animal (steer or cow) was used. Even though the average of 4 sheep is not as satisfactory as 4 individual measurements, it was considered superior to values obtained from a single animal.

After being given a drench of phenothiazine preparation, 16 Hampshire wether lambs were divided into groups of four on the basis of uniform live weight, each group to serve as a unit throughout the entire experiment. An experimental period for each group consisted of a transition period of 7 days, a preliminary period of 7 days, a period of 11 days for the collection of feces and urine and finally a period in the respiration chamber during which the CO_2 and CH_4 were measured during 48 hours. The sheep were kept in individual crates except during the transition period when they were allowed the freedom of a pen.

The sheep crates used were similar to those referred to by Swift *et al.* (1947) but were modified and improved so that no harness was necessary. The advantages resulting from the elimination of collection bags, leaving the animals entirely unhampered in freedom of movement, are quite obvious.

Heat production computed by the balance of nitrogen and carbon method has deen consistently concordant with the results of direct calorimetry simultaneously obtained over a period of many years at this laboratory. It was decided, therefore, to omit the direct heat measurement making it possible for a single operator to attend the apparatus. Collection periods ended before the sheep entered the calorimeter. While in the chamber the four sheep, in individual pens, stood upon a heavy wire screen floor beneath which was placed a 3 inch layer of dry sawdust to absorb the urine. Drinking water was available at all times and the animals were fed twice each day. About

three minutes were required by the man admitted to the chamber to feed the sheep. His estimated carbon dioxide production was subtracted from the total CO_2 produced.

One of the objectives in this experiment was to determine the methane as there are no data in the literature on the methane production of sheep. In addition to the routine preliminary testing of the apparatus a special test was made to determine its accuracy of methane measurement. A known weight of the gas was introduced into the chamber from a cylinder, during a period of several hours and at a rate comparable to that prevailing in the experiments with sheep. Measured aliquots of outcoming air were made CO_2- and water-free by passage through proper absorbers. This dry CO_2-free air was then drawn through an electric combustion furnace containing platinized kaolin where the methane was ignited to CO_2 and water. The resulting CO_2 was weighed and computed to methane. Reasonably satisfactory recovery of the methane introduced into the chamber was obtained (96.5%).

Ration components and feces were sampled for analysis as described in an earlier paper (Swift *et al.*, 1947). The daily urine sample from each sheep was made up to volume and three aliquots taken. One aliquot, preserved with H_2SO_4, was used in making a composite sample for the period and on which nitrogen was determined. The second aliquot was preserved with sodium fluoride for the determination of carbon. The third aliquot was dried daily in a flat bottom Pyrex dish and at the end of the collection period, the nitrogen and energy content were determined. Energy values (large Calories) obtained by the bomb calorimeter, were corrected for loss on drying by multiplying the nitrogen lost in grams by 5.447.[2]

In the planning of the experimental rations it seemed necessary to choose between two somewhat imperfect procedures. One alternative was to add fat to a basal ration and to feed the same amount of basal ration in all periods but with different amounts of added fat. The chief objection to this procedure was that a different energy intake would result with each increase of dietary fat. A second alternative was to keep the energy intake identical in all periods, adding to the basal ration mixtures of fat (corn oil) and carbohydrate (cerelose), the gross energy of the mixture being the same in all periods, with reciprocal variation in the energy content of the two components. This latter procedure, which was the one adopted in this experiment permitted identical intakes of energy, protein, crude fiber, etc. in all periods but involved two variables (corn oil and cerelose). With herbiverous animals equality of feed intake, characterized by identical amounts of protein

[2] This factor corresponds to a heat of combustion value of urea of about 2.54 Cal. per gram. Some of the recent handbooks erroneously list the heat of combustion value of urea as 2.14 Cal. per gram.

and energy, may be more apparent than real. The iso-caloric substitution of fat for soluble carbohydrate, or vice versa, is a process which can be only partly successful in providing equal available energy to the animal. Soluble carbohydrate added to a normal mixed ration decreases the percentage digestibility of the energy, protein, and crude fiber (Swift *et al.*, 1947). These effects are brought about by alteration in the fermentation processes in the rumen so that equal energy and protein intake does not in this case signify actual equality of these items available to the body proper. Thus, any benefit of increased dietary fat under such experimental conditions is inseparable from that which may be the result of the concomitant decreased amount of soluble carbohydrate. The authors appreciate the imperfection in the conditions imposed which, however, seemed to be the best that could be devised.

Since the earlier work (Swift *et al.*, 1947) showed that 9.7% of ether extract in the ration resulted in decreased digestibility thus indicating that this amount was above the optimum, it was decided to feed 6 rations containing respectively, approximately 3, 4, 5, 6, 7 and 8% of ether extract and to have all 16 sheep receive each of the 6 rations.

Before the beginning of each set of 4 consecutive experimental periods, the portions of hay were weighed and put in paper bags. Samples for analysis were taken at this time. Concentrate mixtures for each ration were weighed and mixed in an electric mixer at the start of the experiment. The large quantities of each constituent involved were weighed to the nearest gram in the proportions shown in table 1. The concentrate mixtures were stored at 0°F. An amount sufficient for several days was removed from the refrigerator from time to time, individual feed portions being weighed daily and put in the paper bags with the hay. It was found necessary in the case of the 2 rations containing the most fat, however, to weigh the portions of these concentrate mixtures into beakers inasmuch as the paper bags would absorb some of the fat. The feed from the beakers was then transferred directly to the mangers. The sheep were fed twice a day, water being available at all times.

The order of the 24 periods in which the 6 rations were fed to the 4 groups of sheep was planned to eliminate any possible effects of season and size or age of the sheep. However, in the case of ration 3, which contained no added fat but which did furnish the maximum amount of cerelose, the sheep refused to consume the ration. Consequently, three of these four periods (Nos. 1, 12 and 15) were postponed and were scheduled later as Nos. 25, 27 and 28 respectively, when an equicaloric quantity of sucrose was used in the place of the cerelose. Period 22 with ration 3 was run as originally scheduled but with sucrose as the carbohydrate.

It was planned to secure results from 16 sheep on each of the 6 rations but due to unavoidable difficulty (chiefly feed refusal) only 12 animals completed the entire experiment on ration 3 and 15 on ration 4 (table 4). However, complete digestibility data were obtained from 14 sheep on ration 3 and from 15 sheep on ration 4 (table 3).

It is of considerable interest to note that while sheep prefer cerelose to starch (Swift *et al.*, 1947), sucrose is more readily consumed than either one. In adjusting the program to repeat the periods of highest carbohydrate intake, using sucrose in place of cerelose, an otherwise vacant period (No. 26) was used to feed a ration containing 10.5% of fat. This high fat ration was made simply by adding corn oil to the basal ration and furnished considerable more energy than did the other rations all of which were isocaloric. This ration as well as the others high in fat (corn oil) was consumed with evident relish.

The composition of the alfalfa hay and concentrate mixtures used in the experiment is shown in table 2. The hay was of excellent quality, baled green, and spread out to dry without heat in the barn loft.

Results and Discussion

Table 3, representing a total of 1,067 sheep days, exhibits the average digestibility coefficients of the feed constituents in the different rations. The values for ration 12 were obtained from only 4 sheep and, as explained above, the energy intake of this period was not the same as for the other periods. Results from period 12, therefore, are not directly comparable to the others shown in the table. As the fat content of the ration increased, the percentage digestibility of the ether extract increased in a perfectly regular manner. It is natural that the addition of a highly digestible fat should increase the digestibility of the ether extract of the entire ration. Similarly, the digestibility of the nitrogen-free extract decreased regularly with decrease of this constituent in the ration. There was a definite trend toward a decrease in the digestibility of dry matter with increase of fat in the ration.

The variation in digestibility among sheep receiving a given ration. under carefully controlled conditions, has been worked out (Forbes *et al.*, 1946). According to this study, when ten sheep are used on a treatment, differences in dry matter digestibility must be at least 1% in order to be significant (odds 19 to 1). Since more than ten sheep were used here the differences would not have to be quite so large.

Rations 4 and 5 do not show a significant decrease in digestibility of dry matter when compared to ration 3. Ration 6 however, compared to ration 3 reveals a significant drop. Differences are significant between rations 3 and 6, 4 and 7, and 5 and 8. In other words the difference in composition of rations

TABLE 1. SCHEDULE OF EXPERIMENTATION AND COMPOSITION OF RATIONS

Ration No.	Period No.	Sheep group No.	Rations fed daily						Collection period		Calorimeter period	
			Alfalfa hay	Composition of concentrate mix*					Start	End	Start	End
				Corn meal	Linseed oilmeal	Corn	Cerelose	Sucrose				
			gm.	gm.	gm.	gm.	gm.	gm.				
3	22	B	420	420	48	—	—	118.2	May 2	May 13	May 14	May 16
	25	A	420	420	48	—	—	118.2	May 23	June 3	June 4	June 6
	27	C	420	420	48	—	—	118.2	June 6	June 17	June 18	June 20
	28	D	420	420	48	—	—	118.2	June 13	June 25	June 25	June 27
4	3	C	420	420	48	13.3	98.3	—	Dec. 13	Dec. 24	Dec. 25	Dec. 27
	10	B	420	420	48	13.3	98.3	—	Feb. 7	Feb. 18	Feb. 19	Feb. 21
	13	A	420	420	48	13.3	98.3	—	Feb. 28	Mar. 11	Mar. 12	Mar. 14
	24	D	420	420	48	13.3	98.3	—	May 16	May 27	May 29	May 31
5	5	A	420	420	48	22.2	73.7	—	Jan. 3	Jan. 14	Jan. 15	Jan. 17
	11	C	420	420	48	22.2	73.7	—	Feb. 14	Feb. 25	Feb. 26	Feb. 28
	16	D	420	420	48	22.2	73.7	—	Mar. 21	Apr. 1	Apr. 2	Apr. 4
	18	B	420	420	48	22.2	73.7	—	Apr. 4	Apr. 15	Apr. 16	Apr. 18
6	4	D	420	420	48	31.1	49.1	—	Dec. 20	Dec. 31	Jan. 1	Jan. 3
	6	B	420	420	48	31.1	49.1	—	Jan. 10	Jan. 21	Jan. 22	Jan. 24
	17	A	420	420	48	13.1	49.1	—	Mar. 28	Apr. 8	Apr. 9	Apr. 11
	23	C	420	420	48	31.1	49.1	—	May 9	May 20	May 21	May 23
7	7	C	420	420	48	40.0	24.6	—	Jan. 17	Jan. 28	Jan. 29	Jan. 31
	9	A	420	420	48	40.0	24.6	—	Jan. 31	Feb. 11	Feb. 12	Feb. 14
	14	B	420	420	48	40.0	24.6	—	Mar. 7	Mar. 18	Mar. 19	Mar. 21
	20	D	420	420	48	40.0	24.6	—	Apr. 18	Apr. 29	Apr. 30	May 2

TABLE 1 (*continued*)

8	2	B	420	420	48	48.8	—	—	Dec. 6	Dec. 17	Dec. 19	Dec. 21
	8	D	420	420	48	48.8	—	—	Jan. 24	Feb. 4	Feb. 5	Feb. 7
	19	C	402	420	48	48.8	—	—	Apr. 11	Apr. 22	Apr. 23	Apr. 25
	21	A	420	420	48	48.8	—	—	Apr. 25	May 6	May 7	May 9
12	26	B	420	420	48	84.4	—	—	May 30	June 10	June 11	June 13

* Plus 3 gms. NaCl.

TABLE 2. COMPOSITION OF FEEDING STUFFS

Feeding stuff	Period Nos.	Dry matter	Composition of dry matter					
			Crude protein	Ether extract	Ash	Crude fiber	N-free extract	Energy
		percent	*percent*	*percent*	*percent*	*percent*	*percent*	cal./gm.
Alfalfa hay	2, 3, 4	90.09	15.96	2.11	7.37	36.92	37.63	4,460
Alfalfa hay	5, 6, 7, 8	91.32	17.18	2.07	7.42	33.71	39.61	4,461
Alfalfa hay	9, 10, 11	91.11	16.33	1.99	7.41	35.88	38.39	4,454
Alfalfa hay	13, 14, 16	91.50	16.60	2.20	7.79	34.58	38.85	4,480
Alfalfa hay	17, 18, 19, 20	89.26	18.27	2.05	7.74	31.97	39.96	4,598
Alfalfa hay	21, 22, 23, 24	90.62	17.17	2.01	7.91	31.27	41.64	4,499
Alfalfa hay	25, 26, 27, 28	90.23	17.32	2.09	7.85	31.82	40.95	4,500
Concentrate mixture	22	90.50	9.73	3.80	2.04	2.51	81.92	4,359
Concentrate mixture	25, 27, 28	90.78	9.78	3.76	2.02	2.49	81.97	4,364
Concentrate mixture	3, 10, 13, 24	89.00	9.90	6.44	2.02	2.57	79.08	4,475
Concentrate mixture	5, 11, 16, 18	88.78	10.21	8.70	2.16	2.71	76.23	4,615
Concentrate mixture	4, 6, 17, 23	88.76	10.57	10.41	2.10	2.77	74.17	4,730
Concentrate mixture	7, 9, 14, 20	89.12	10.87	12.59	2.14	2.93	71.49	4,868
Concentrate mixture	2, 8, 19, 21	89.15	11.43	14.97	2.20	3.01	68.40	4,978
Concentrate mixture	26	90.41	10.30	18.73	2.18	2.71	66.09	5,210

TABLE 3. DIGESTIBILITY OF RATION CONSTITUENTS

Ration No.	No. of sheep	Dry matter	Crude fiber	Crude protein	Ether extract	N-free extract	Energy
		percent	*percent*	*percent*	*percent*	*percent*	*percent*
3	14	79.0	43.8	72.2	72.8	90.0	76.7
4	15	78.6	49.4	70.8	82.6	89.0	76.3
5	16	78.2	48.0	71.9	85.5	88.5	76.4
6	16	77.3	47.0	71.8	86.7	87.4	75.8
7	16	77.4	49.9	72.7	87.6	86.9	75.7
8	16	76.6	47.2	73.5	88.5	86.1	75.0
12	4	76.4	45.7	72.1	90.1	84.4	75.3

differing by only one percent of fat was not large enough to produce scarcely any significant differences in digestibility but when differences of 3% in fat content of the ration are considered, the differences are significant. A similar trend is seen in the digestible energy, differences of 3% in the fat conent of the rations being necessary for confident interpretation. No consistent effect is evident in the case of the crude protein or crude fiber.

The sheep were shorn from April 18 to May 9, immediately following a period of observation in the respiration chamber, groups B, C, D, A, being shorn after periods 18, 19, 20, and 21 respectively. Since it was necessary to keep the sheep in an unheated shed during the transition periods, the sheep were not shorn until the weather had moderated. There is a possibility that the sheep, with a full coat of wool, while in the crates and in the respiration chamber especially during the periods just prior to shearing, were exposed to a temperature which was above the point of hyperthermal rise. The temperature of the respiration chamber was maintained at 14.7° C. For the best controlled work in energy metabolism it would be preferable to shear the sheep at frequent intervals and to provide facilities which would insure against large fluctuations in environmental temperature.

Table 4 presents a summary of the energy exchange of the sheep receiving the different rations and represents a total of 190 24-hour sheep days during which the production of heat and methane was determined. Of the 6 isocaloric rations, No. 3, containing the maximum amount of added carbohydrate, not only resulted in the smallest digestibility of the crude fiber (table 3) but also gave the lowest value for metabolizable energy and heat production. The heat production from ration 12 was decidedly less than from the other 6 rations although it furnished more gross energy and more metabolizable energy. This difference in heat production may be somewhat discounted on account of the large correction for change in live weight and by the fact that only a single group of 4 sheep was used. However, the au-

TABLE 4. METABOLIZABLE ENERGY, HEAT AND METHANE PRODUCTION PER SHEEP PER DAY

Ration	No. of sheep	Ave. live weight	Intake	Metabolizable energy	Heat production*	Methane
		lb.	Cal.	Cal.	Cal.	Cal.
3	12	119.8	3,953	2,520	1,911	324
4	15	107.6	4,024	2,614	1,994	313
5	16	110.6	4,042	2,637	1,954	301
6	16	107.6	4,026	2,600	2,013	296
7	16	110.0	4,040	2,612	1,945	292
8	16	108.0	4,017	2,571	1,932	284
12	4	125.3	4,324	2,897	1,754	223

* Corrected to 110 lbs. live wt. in accord with the .73 power of the live weight.

thors feel that it may well signify an increase in efficiency of food utilization with increase in dietary fat. The increase in metabolizable energy was somewhat more than the increase in gross intake. More evidence is required for a clear demonstration. The limited range in values for metabolizable energy and heat production obtained with the other five rations (No. 4 to 8 inclusive) merely attests to the validity of the work and indicates no significant difference in energy utilization between the rations.

The average daily gain of nitrogen for the 6 isocaloric rations was 2.0 gms.; the daily gain of nitrogen from the ration containing 10.5% fat was 2.4 gms.

In view of the previous work (Swift *et al.*, 1947) in which increased digestibility of all ration constituents occurred when the fat intake level was raised from 2.8% to 6.4% it was hoped that an optimum level could be determined by the present experiment. In the experiment referred to, fat (corn oil) was added to a mixed ration; isocaloric substitution was not involved. The difference in the methods of feed assignment in the two cases may be responsible for the disparity in results, for apparently, the associative effects of a simultaneously higher fat and lower carbohydrate intake are too complex to give a clear picture when considered in relation to either one of these two variables alone. A further difficulty experienced in employing isocaloric feed intake in this particular experiment was the problem encountered in getting the sheep to eat the larger amounts of carbohydrate.

The average caloric value of the methane shown in the column at the extreme right constitutes 7.5% of the value of the total energy intake. This percentage is similar to previous values obtained with cattle.

The nitrogen, carbon, and energy were determined on each of 93 samples of urine collected throughout the experiment. The relationship between these items is shown in table 5.

TABLE 5. RELATIONSHIP BETWEEN URINARY NITROGEN, CARBON, AND ENERGY

Item		Coefficient of variation
Gm. carbon per gm. N	1.485	4.04±0.04
Cal. per gm. N	13.45	4.46± .04
Cal. per gm. C	9.06	4.42± .03

In the employment of the nitrogen and carbon balance method of indirect calorimetry, it is necessary to know the energy of the urine. If this can be accurately computed from the carbon content, direct determination of the energy by use of the bomb calorimeter is unnecessary. In this experiment the energy of the urine as directly determined amounted to 9.06 Cal. per gram of carbon with a rather low coefficient of variation (4.42%). As a matter of fact, in this experiment, the Calories per gram of nitrogen would be about as reliable as the factor based on the carbon, the ratio between C and N being very consistent. This is true because, as previously stated, the nitrogen intake was the same in all periods. Ordinarily, for rations of different protein contents the ratio of carbon to energy should be less variable than the ratio—nitrogen to energy—and would be the one ordinarily employed in computing the urinary energy.

In previous work at our laboratory a statistical study was made of results obtained with cattle concerning the relationship between methane production and various ration characteristics. The object of this study was to derive a formula by means of which methane production could be computed with sufficient accuracy for the computation of approximate metabolizable energy values of feeding stuffs for cattle. Of all relationships tested, the one between methane produced and carbohydrate digested was the most significant.

From the methane produced and carbohydrate digested during 24 feeding periods of the experiment being reported here, the regression coefficient, computed by the method of least squares, gave the formula: $E=2.41X+9.80$, in which E signifies grams of methane produced and X represents hundreds of grams of carbohydrate digested. The formula obtained from similar treatment of results previously obtained with cattle (Bratzler and Forbes, 1940) is, $E=4.012X+17.68$. Because the formulas obtained in the above manner depend directly on the magnitude of the values obtained (methane produced and carbohydrate digested), each of the formulas can be used only with the type of animal from which it was derived. That is, the formula obtained from results with sheep can be used only with sheep and that obtained from results with cattle only with cattle.

While the computation of quantities of methane produced, is not advocated for critical purposes, the above formulas are proposed as a means of computing methane for uses which may be served by approximate values.

Summary

Six rations, made isocaloric by reciprocal variation between added fat and carbohydrate and containing 3, 4, 5, 6, 7 and 8% ether extract respectively, and furnishing equal amounts of protein were fed to a group of 16 sheep. Digestibility, heat production, and methane were determined, the utilization of protein and energy being about the same for all 6 rations. The effects of reciprocal variation between added dietary fat and carbohydrate makes difficult the assignment of results to either one of these two ration components. Based on the amount of carbohydrate digested, a formula is given for the production of methane by sheep.

Literature Cited

Bratzler, J. W. and E. B. Forbes. 1940. The Estimation of Methane Production by Cattle. Jour. Nutrition 19: 611.

Forbes, E. B., Ralph F. Elliott, R. W. Swift, W. H. James and Vivian Frances Smith. 1946. Variations in Determinations of Digestive Capacity of Sheep. JOURNAL OF ANIMAL SCIENCE 5: 298.

Forbes, E. B., R. W. Swift, R. F. Elliott and W. H. James. 1946a. Relation of Fat to Economy of Food Utilization. I. By the Growing Albino Rat. Jour. Nutrition 31: 203.

———. 1946b. II. By the Mature Albino Rat. Jour. Nutrition 31: 213.

Forbes, E. B., R. W. Swift, W. H. James, J. W. Bratzler, and Alex Black. 1946c. Further Experiments on the Relation of Fat to Economy of Food Utilization. I. By the Growing Albino Rat. Jour. Nutrition 32: 387.

Forbes, E. B., R. W. Swift, E. J. Thacker, Vivian Frances Smith and C. E. French. 1946d. Further Experiments on the Relation of Fat to Economy of Food Utilization. II. By the Mature Albino Rat. Jour. Nutrition 32: 397.

Lucas, H. L. and J. K. Loosli. 1944. The Effect of Fat Upon the Digestion of Nutrients by Dairy Cows. JOURNAL OF ANIMAL SCIENCE 3:3.

Maynard, L. A. and C. M. McCay. 1929. The Influence of a Low-Fat Diet upon Fat Metabolism During Lactation. Jour. Nutrition 2: 67.

Maynard, L. A. and C. M. McCay. 1932. The Influence of Different Levels of Fat Intake upon Milk Secretion. 1932. Cornell Bull. 543.

Maynard, L. A., C. M. McCay, H. H. Williams and L. L. Madsen. 1934. Further Studies of the Influence of Different Levels of Fat Intake upon Milk Secretion. Cornell Bull. 593.

Maynard, L. A., K. E. Gardner and Adrian Hodson. 1939. Soybeans as a Source of Fat in the Dairy Ration. Cornell Bull. 722.

Maynard, L. A., J. K. Loosli and C. M. McCay. 1940. Further Studies of the Influence of Fat Intake on Milk and Fat Secretions. Amer. Soc. Anim. Prod., Proc., pp. 340–344.

Maynard, L. A., J. K. Loosli and C. M. McCay. 1941. III. Further Studies of the Influence of Different Levels of Fat Inake upon Milk Secretion. Cornell Bull. 753.

Monroe, C. F. and W. E. Krauss. 1940. The Relationhip of Fat Content in the Dairy Rations to Milk and Butterfat Production. Jour. Dairy Sci. 23: 558.

Swift, R.W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. The Digestibility of Rations for Ruminants as Affecte by Proportions of Nurtients. JOURNAL OF ANIMAL SCIENCE 6: 432.

RAISING NEWBORN PIGS TO WEANING AGE ON A SYNTHETIC DIET WITH ATTEMPT TO PRODUCE A PTEROYLGLUTAMIC ACID DEFICIENCY

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In 1945 work was started at Illinois on the development of a "synthetic" diet for young calves in order to study the water-soluble vitamin requirements of ruminants. Since the "synthetic milk" diet developed was used successfully in the rearing of calves, it appeared worthwhile to attempt to rear baby pigs on the same diet.

It was hoped that by starting with the very young animal it might be possible to produce deficiencies that do not appear in weanling or older pigs. Such animals would not have an opportunity to build up large body stores of the vitamins from the sow's milk and their rapid rate of growth should mean high requirements. Thus, the baby pig seemed an ideal experimental animal with which to study certain nutritive requirements of swine. It was also hoped that studies on baby pigs would lead to useful information applicable to infant nutrition.

Experimental Procedures, Results, and Discussion

Experiment 1. Two-weeks-old pigs

Since it was not known at what age it would be possible to train baby pigs to drink from a pan, the first group was started at 2 weeks of age. Ten 2-weeks-old Duroc-Jersey pigs from the same litter were fed the "synthetic milk" ration, previously used with very young calves, the composition of which is as follows:

"Labco vitamin-free" casein	30.0
Cerelose	37.4
Lard	26.6
Salts	6.0

[1] Thiamine hydrochloride, riboflavin, pyridoxine hydrochloride, calcium pantothenate, biotin, nicotinic acid and α-tocopherol acetate were generously supplied by Hoffmann-La Roche, Inc., Nutley, New Jersey, through the courtesy of Dr. J. C. Bauernfeind. Pteroylglutamic acid was generously supplied by the Lederle Laboratories Division, American Cyanamid Co., Pearl River, New York, through the courtesy of Dr. Tom Jukes. Choline was supplied by Merck and Co., Inc., Rahway, New Jersey, and inositol, by the A. E. Staley Manufacturing Co., Decatur, Illinois. Sulfathalidine (phthalylsulfathiazole) was generously supplied by Sharp and Dohme, Inc., Philadelphia, Pennsylvania, through the courtesy of Dr. S. F. Scheidy. Hyflavin (a highly water soluble form of riboflavin) was generously supplied by Endo Products, Inc., Richmond Hill, New York.

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The composition of the salt mixture is:

NaCl	356
K_2HPO_4	773
$CaHPO_4$	1014
$MgSO_4$	106
$CaCO_3$	686
Ferric citrate · 6 H_2O	58
KI	1.7
$MnSO_4$	3.0
$ZnCl_2$	0.5
$CuSO_4 \cdot 5\ H_2O$	0.6
$CoCl_2$	0.2
CaF_2	1.0
	3000.0

This ration was prepared as described previously (Wiese, Johnson, Mitchell, and Nevens, 1947). The milk, as made up, contained the fat-soluble vitamins per liter as follows:

Vitamin A	1000 I.U.
Vitamin D_2	100 I.U.
α-tocopherol acetate	1 mg.
2-methyl-1,4-naphthoquinone	0.26 mg.

The water-soluble vitamins, which were not included in the milk as prepared were added, in a 20 percent alcohol solution, to this milk at each feeding at the following rate per liter:

Thiamine chloride	0.65 mg.	Choline	260.0 mg.
Riboflavin	1.30 mg.	PABA	2.6 mg.
Pyridoxine hydrochloride	0.65 mg.	PGA	0.052 mg.
Calcium pantothenate	7.8 mg.	Biotin	0.01 mg.
Inositol	26.0 mg.	Nicotinic acid	2.6 mg.

The pigs in this experiment were housed in individual wire-bottom cages and were fed four times daily (at about 8 A.M., 1 P.M., 5 P.M., and 9 P.M.). The "synthetic milk" ration was given to each pig in a shallow rabbit dish and the pigs were taught to drink by submerging their snouts in the "milk" (warmed to 37° C.) when they became hungry. After two or three days the milk was fed at refrigerator temperature. The pigs were fed *ad libitum*, i.e., enough milk was given at each feeding so that a small amount would still be left in the dish at the time of the next feeding. After about two weeks, the rabbit dishes became too small and were replaced by 8-pint enamelware

saucepans placed in a holder in each cage so that the pig could not upset them.

The pigs learned to drink from dishes within a day and no difficulties were encountered using this method of feeding. The only change that was made in the second and third experiments was to feed only three times per day (8 A.M., 2 P.M., 8 P.M.), which was just as satisfactory, as shown by excellent growth of pigs on the complete "synthetic milk" ration.

The ten pigs were individually fed in 2 groups of 5 pigs each. Group 1 received the complete ration and group 2 received the same ration with the pteroylglutamic acid omitted. All pigs received sulfathalidine at the rate of 3 grams per liter of milk throughout the experiment (2 percent on the dry basis). This was done to inhibit intestinal synthesis in the attempt to produce a PGA deficiency in group 2. These pigs were kept on this regime until 8 weeks of age. Their growth curves are shown in figure 1.

A small difference in growth rates is apparent and is statistically significant at a probability level of 0.022 (Student, 1925). There was also a difference in hair color, those on the PGA-low rations having lighter colored haircoats.

Blood samples were taken from all pigs at weekly intervals and hemoglobin values, red blood cell and white blood cell counts were determined. Blood smears were also made. No significant differences were found between the two groups with regard to hemoglobin concentration, red blood cell or white cell counts, and no pathology of the cells was observed.

Experiment 2. Four-day-old pigs

Having shown that 2-weeks-old pigs could be successfully fed and raised on the "synthetic milk," a second group of 10 Duroc-Jersey pigs was started at the age of 4 days. These pigs were divided into two groups of 5 pigs each and each group was fed as in experiment 1, except that the pigs were fed 3 times daily instead of 4. The growth curves of these pigs are shown also in figure 1.

In experiment 2 there was no significant difference in growth rate, hair color, or blood picture between the two groups.

In this experiment we were unable to produce any evidence of a pteroylglutamic acid deficiency in 7 weeks on the pteroylglutamic acid-low synthetic diet containing 2 per cent sulfathalidine.

Experiment 3. One-day-old pigs

A third group of pigs (Chester Whites and Duroc-Jerseys) were raised on the "synthetic milk" ration. In this experiment 6 Chester White pigs were started at one day of age and 3 Duroc-Jerseys, at 4 days of age. Figure 2

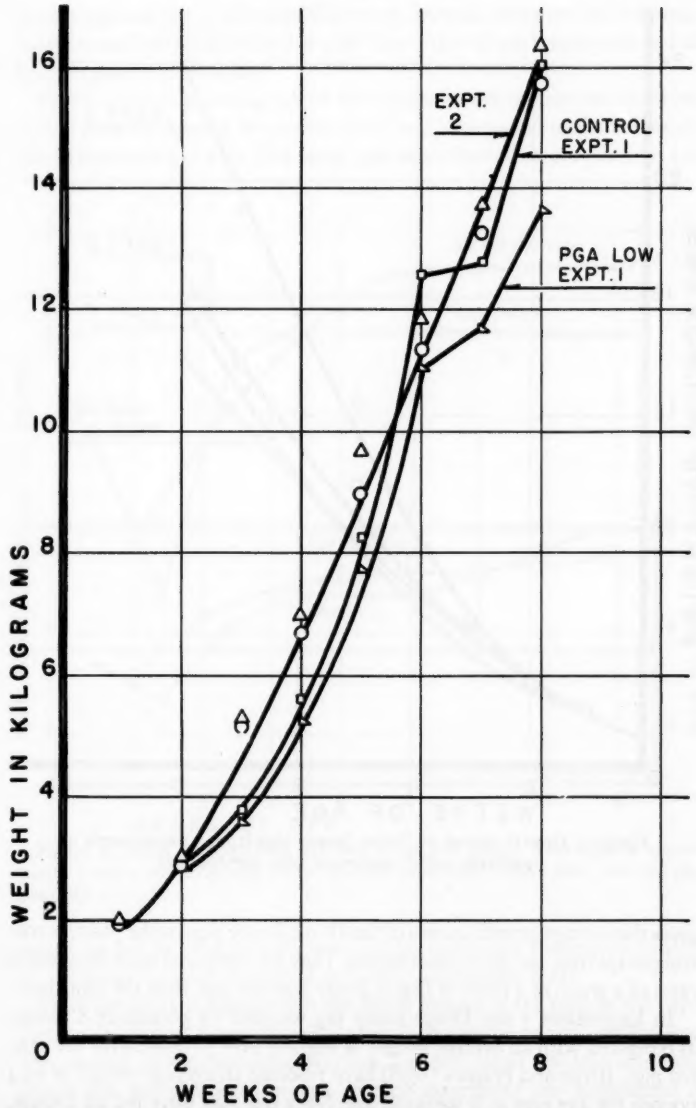

Figure 1. Growth curves of pigs on "synthetic milk" diet. Experiment 1. Control received the complete ration; PGA-low received the pteroylglutamic acid-low ration. Experiment 2. ○ received the complete ration; △ received the PGA-low ration.

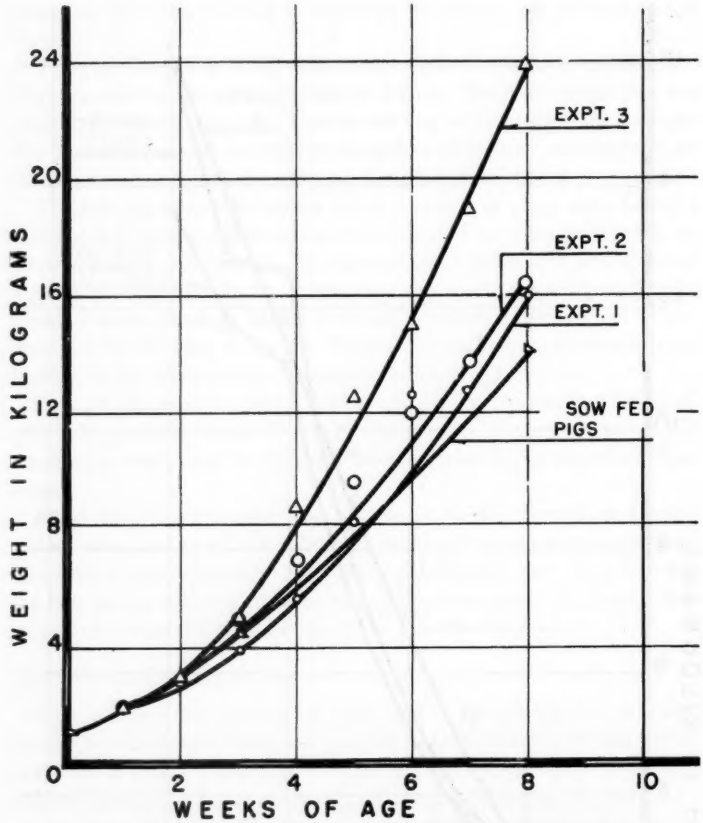

Figure 2. Growth curves of Duroc-Jersey pigs from 3 experiments on "synthetic milk" compared with sow-fed pigs.

gives the average growth curves of the Duroc-Jersey pigs in the positive control groups from the three experiments. They are compared with the growth rates of a group of 4 liters of Duroc-Jersey sow-fed pigs from the same herd.

In Experiment 3 one Duroc-Jersey pig weighed 53 pounds at 8 weeks, as compared with an average weight of slightly over 30 pounds for the sow-fed pigs. Ittner and Hughes (1938) have reported an average weight of 29.4 pounds for 457 pigs at 8 weeks of age. Since our pigs were fed *ad libitum*, this improved growth is probably merely a reflection of the limited milk-

producing capacity of the sow. Weybrew, Stewart, Peterson and Matrone (1947) raised baby pigs on cow's milk from 1 day of age which averaged almost 50 pounds at 8 weeks.

Figure 3 gives the average blood hemoglobin values and the red blood cell counts from all the pigs of experiments 1 and 2 compared to the values obtained from sow-fed pigs. The latter pigs were treated to prevent iron and

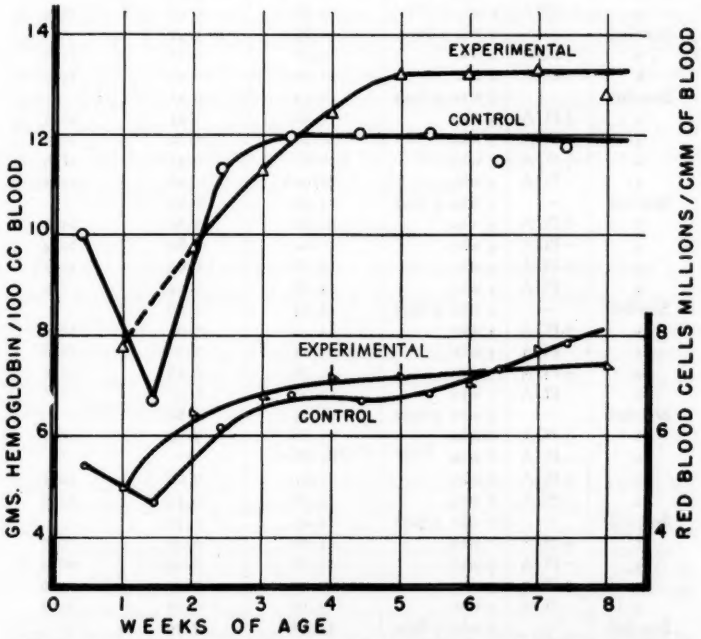

Figure 3. Blood hemoglobins and red blood cell counts from pigs in experiments 1 and 2 on "synthetic milk" diets as compared to data from sow-fed pigs (control).

copper anemia by swabbing the sow's udder daily with a saturated solution of "copperas" so long as the pigs were kept on concrete floors.

From the chart it appears that the blood picture of the pigs on the "synthetic milk" ration is essentially the same as that of the normal sow-fed pigs. The average hemoglobin concentration, and red blood cell and white cell counts for the individual groups in each experiment are summarized in table 1.

TABLE 1. AVERAGE BLOOD DATA FROM "SYNTHETIC MILK" FED BABY PIGS AND SOW-FED BABY PIGS

Expt. name or no.	Group	Age	Hemoglobin gm/100 cc	Red blood cells millions/cmm	White blood cells thousands/cmm
Sow-fed	—	3 days	10.05	5.44	
2	+PGA	1 wk.	7.68	4.66	18.0
2	−PGA	1 wk.	7.98	5.11	13.4
Sow-fed	—	1 wk. 3 days	6.69	4.72	
2	+PGA	2 wk.	9.06	6.11	11.2
2	−PGA	2 wk.	10.36	6.73	14.0
Sow-fed	—	2 wks. 3 days	11.33	6.11	
1	+PGA	3 wks.	11.90	7.23	20.5
1	−PGA	3 wks.	10.28	6.29	16.8
2	+PGA	3 wks.	11.25	6.33	15.9
2	−PGA	3 wks.	11.90	7.26	14.1
Sow-fed	—	3 wks. 3 days	11.96	6.79	
1	+PGA	4 wks.	12.12	7.86	21.7
1	−PGA	4 wks.	12.04	6.80	20.4
2	+PGA	4 wks.	12.98	6.99	10.1
2	−PGA	4 wks.	12.66	6.94	9.2
Sow-fed	—	4 wks. 3 days	12.04	6.66	
1	+PGA	5 wks.	14.46	7.62	18.9
1	−PGA	5 wks.	13.58	7.71	16.8
2	+PGA	5 wks.	11.76	6.56	15.5
2	−PGA	5 wks.	12.68	6.91	10.6
Sow-fed	—	5 wks. 3 days	12.03	6.82	
1	+PGA	6 wks.	13.66	7.59	16.1
1	−PGA	6 wks.	13.16	—	—
2	+PGA	6 wks.	13.95	7.08	12.1
2	−PGA	6 wks.	12.36	6.59	11.6
Sow-fed	—	6 wks. 3 days	11.49	7.30	
1	+PGA	7 wks.	13.68	8.42	16.7
1	−PGA	7 wks.	14.16	8.26	20.5
2	+PGA	7 wks.	12.05	7.95	13.6
2	−PGA	7 wks.	13.10	6.25	10.5
Sow-fed	—	7 wks. 3 dyas	11.78	7.79	
1	+PGA	8 wks.	12.92	7.41	12.4
1	−PGA	8 wks.	12.94	7.51	11.3
2	+PGA	8 wks.	12.53	7.24	12.1
2	−PGA	8 wks.	13.00	7.26	12.2

Discussion

From these experiments it seems evident that baby pigs one day old or older can be satisfactorily raised to weaning age (8 weeks) on a "synthetic milk" ration.

In the first experiment the lower growth rate and the lighter hair coats of the pigs fed the PGA-low ration indicates a beginning PGA deficiency. This

deficiency was not evident in the blood picture, presumably because of the short experimental period. Another symptom which appeared on these deficient pigs was the appearance of a black exudate around the eyes. This is apparently not a specific symptom in that is has been noted in other deficiencies as well, by McRoberts and Hogan (1944) by Cartwright, Wintrobe and Humphreys (1946) and by Bustad, Ham and Cunha (1947).

In the second experiment no evidence of a PGA deficiency occurred. This is probably due to better initial stores of PGA in the pigs but may be a reflection of a higher PGA intake from a different lot of vitamin-free casein or a less successful suppression of intestinal synthesis. This inability to produce a severe PGA deficiency in pigs fed a synthetic diet is in agreement with work using older pigs reported by Cunha *et al.* (1947) and by Welch *et al.* (1947). The latter authors were able to produce the PGA deficiency syndrome in one pig by the use of a PGA antagonist.

Conclusions

Pigs which received colostrum for a minimum of 24 hours have been successfully raised to 8 weeks of age on a "synthetic" ration made up to simulate cow's milk.

A clear-cut deficiency of pteroylglutamic acid has not been consistently produced on a synthetic diet lacking the vitamin, even with the addition of a bacteriostatic agent (sulfathalidine).

Literature Cited

Bustad, L. K., W. E. Ham and T. J. Cunha. 1947. Preliminary Observations on Using a Synthetic Milk for Raising Pigs from Birth. JOURNAL OF ANIMAL SCIENCE 6: 484.

Cartwright, G. E., M. M. Wintrobe and S. Humphreys. 1946. Production of Anemia in a Pig which Responded to Purified Liver Extract. Journal Lab. Clin. Med. 31: 423–427.

Cunha, T. J., L. K. Bustad, W. E. Ham, D. R. Cordy, E. C. McCulloch, T. F. Woods, G. H. Conner and M. A. McGregor. 1947. Folic Acid, Para-aminobenzoic Acid and Anti-pernicious Anemia Liver Extract in Swine Nutrition. Jour. Nutrition 34: 173–187.

Ittner, N. R. and E. H. Hughes. 1938. A Normal Growth Curve for Swine. Jour. Heredity 29: 165–174.

McRoberts, V. F. and A. G. Hogan. 1944. Adequacy of Simplified Diets for the Pig. Jour. Nutrition 28: 165174.

"Student." 1925. New Tables for Testing the Significance of Observations. Metron 5: 105.

Welch, A. D., R. W. Heinle, G. Sharpe, W. L. George and M. Epstein. 1947. Chemical Antagonism of Pteroylglutamic Acid in a Pig; Hematopoietic Effect of Extrinsic and Intrinsic Factors. Proc.Soc.Expt. Biol. Med., 65: 364–368.

Weybrew, J. A. H. A. Stewart, W. J. Peterson and G. Matrone. 1947. Nutrition Studies with Swine. I. Supplemented Milk Diets for Young Pigs in Cages. JOURNAL OF ANIMAL SCIENCE 6: 492.

Wiese, A. C., B. Connor Johnson, H. H. Mitchell and W. B. Nevens. 1947. Synthetic Rations for the Dairy Calf. Jour. Dairy Sci. 30: 87–94.

FEEDING GRAINS OF DIFFERENT PROTEIN CONTENT[1]

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Introduction

DATA are available, Anderson (1939–41) and Anderson and Aitken (1943–46), to show that marked variations occur in the protein content of grains, depending upon the conditions of soil and climate under which they are grown. As an extreme example, wheat grown on gray soil in the northern section of Alberta may contain as little as 7 to 8 percent protein, as compared to 16 to 17 percent for the same variety grown on brown soil in the southeastern part of the province. Similar differences exist in oats and barley. The wheat industry is vitally interested in these variations because of their effect on the milling and baking quality of wheat, but relatively little study has been given to the question of the effect that differences in protein content of grains may have on their feeding value for livestock. The results of feeding trials conducted with rats and pigs using grains of markedly different protein content are reported in this paper.

Experimental

Nitrogen determinations were done on a large number of samples of grain grown in different regions of the province and, on the basis of these analyses, samples of oats, barley and wheat representing a wide range of protein content were selected and bulk quantities purchased for feeding trials. Data regarding the protein content of the grains used are given in table 1.

Rat Feeding Trial

The animals were kept in individual cages with raised wire screen bottoms. Food and water were supplied *ad libitum* daily. As outlined below, eight groups of six weanling white rats were fed rations in which different grains or combinations of grains constituted the only source of protein, while a ninth group was supplemented with 8% casein.

Group No.	*Ration*
1	Low protein oats
2	High protein oats

[1] This study was conducted with the aid of a grant from the Committee on Agricultural Research Grants, University of Alberta.

[2] Part of the data presented here are taken from a thesis "A Study of the Nutritional Value of Cereal Grain Proteins" submitted by Wm. Lobay in partial fulfillment of the requirements for the degree of Master of Science.

[3] Department of Animal Science, Edmonton, Alberta.

3 Low protein barley
4 High protein barley
5 Low protein wheat
6 High protein wheat
7 Low protein oats+barley, equal parts
8 High protein oats+barley, equal parts
9 Low protein barley+8% vitamin-free casein.

Rations were formulated as follows:

	Groups 1–8 grams	*Group 9* grams
Grain	930	850
Crisco	30	30
Salt mixture[4]	40	40
Vitamin-free casein	–	80

The following vitamin supplements were added to each kilogram of basal mixture: fish oil (3000 I.U. A—400 I.U. D) 3 g., thiamine 10 mg., riboflavin 20 mg., pyridoxine 10 mg., calcium pantothenate 20 mg., niacin 10 mg., biotin 10 micrograms, choline chloride 1 g. In addition, each rat was dosed orally once a week with 2 mg. of α-tocopherol in peanut oil.

Pig Feeding Trial

Recommendations to farmers regarding the mixing of protein supplements with home grown grains for pigs are usually based on the assumption that the grains are "average" with respect to protein content, so that the variables used in calculating levels of supplementation are essentially the weight of the pig and the protein content of the supplement in question. The plan of the pig feeding trial to be described was simply to compare the growth of pigs fed low, medium or high protein oats and barley; (a) with grain as the only source of protein, and (b) when these grains were fortified with a recommended level of a protein supplement. The mixed supplement used contained 43% protein and was constituted as follows: tankage 50, fish meal 15, linseed oil meal 25, ground limestone 5, and iodized salt 5 percent by weight.

Forty-two purebred Yorkshire weanling pigs were divided into six uniform groups of seven pigs each, and were hand-fed three times daily until they reached an average group weight of 110 lbs., and twice daily thereafter with the rations shown in table 2. The pigs were housed in a piggery in 10′ × 12′ pens without access to soil or sunlight.

[4]Mixture 185, McCollum, Simmonds and Pitz (1916), plus 3% iron citrate.

TABLE 1. PROTEIN CONTENT OF GRAINS USED IN RAT AND PIG FEEDING TRIALS

Grain	Protein, percent*	
	Rats	Pigs
Low protein oats	8.2	9.5
Med. protein oats	—	12.3
High protein oats	15.9	16.3
Low protein barley	9.4	9.4
Med. protein barley	—	13.0
High protein barley	16.2	17.1
Low protein wheat	8.9	—
High protein wheat	17.3	—

* Nitrogen was determined using the Kjeldahl method with mercuric oxide as catalyst. Protein in oats and barley is reported as nitrogen ×6.25 and in wheat as nitrogen ×5.7. Results are expressed on the basis of 13.5% moisture.

Results and Discussion

Rats

The results of the rat feeding experiment are summarized in figure 1 and in the following tabulation in which the average gain in weight for each group is expressed as a percentage of that made by the rats in the lot fed high protein barley:

Feed	*Percent*
Low protein barley+8% casein	100.3
High protein barley	100
High protein barley+high protein oats, equal parts	93
High protein oats	89
High protein wheat	79
Low protein barley+low protein oats, equal parts	67
Low protein oats	63
Low protein barley	58
Low protein wheat	39

It is evident that under the conditions of feeding employed in this experiment, differences in growth resulted, both as between groups fed grains of the same species, but of markedly different protein content, and as between groups fed grains of different species but of similar protein analysis. The rate of gain and general appearance of the rats in groups fed wheat rations was appreciably poorer than that of animals in comparable groups fed barley or oats. An interesting feature of these results is that rats fed barley containing

TABLE 2. PIG RATIONS. EIGHT ML. FEEDING OIL** PER PIG PER DAY WERE FED TO ALL GROUPS DURING PERIOD A

Feed	Grain+Minerals+Vitamins						Grain+Minerals+Vitamins+Protein					
	1 L.P.		2 M.P.		3 H.P.		4 L.P.		5 M.P.		6 H.P.	
	A*	B*	A	B	A	B	A	B	A	B	A	B
Low protein oats, lbs.	40	10	—	—	—	—	35	9	—	—	—	—
Low protein barley, lbs.	60	90	—	—	—	—	53	85	—	—	—	—
Med. protein oats, lbs.	—	—	40	10	—	—	—	—	35	9	—	—
Med. protein barley, lbs.	—	—	60	90	—	—	—	—	53	85	—	—
High protein oats, lbs.	—	—	—	—	40	10	—	—	—	—	35	9
High protein barley, lbs.	—	—	—	—	60	90	—	—	—	—	53	85
Iodized salt, lbs.	1	1	1	1	1	1	—	—	—	—	—	—
Ground limestone, lbs.	1	1	1	1	1	1	—	—	—	—	—	—
Mixed supplement, lbs.	—	—	—	—	—	—	12	6	12	6	12	6
Protein in ration, percent	9.3	9.2	12.5	12.7	16.5	16.7	13.5	11.4	16.4	14.7	19.9	18.6

* Period A—start of experiment to 100 lbs., period B—110 lbs. to market weight, all groups.
** The feeding oil contained 200 I.U. vitamin D and 1500 I.U. vitamin A per gram.

16.2% protein grew at practically the same rate as those fed a 9.4% protein barley supplemented with 8% washed casein, which suggests that barley protein may be a reasonably high quality protein for rats.

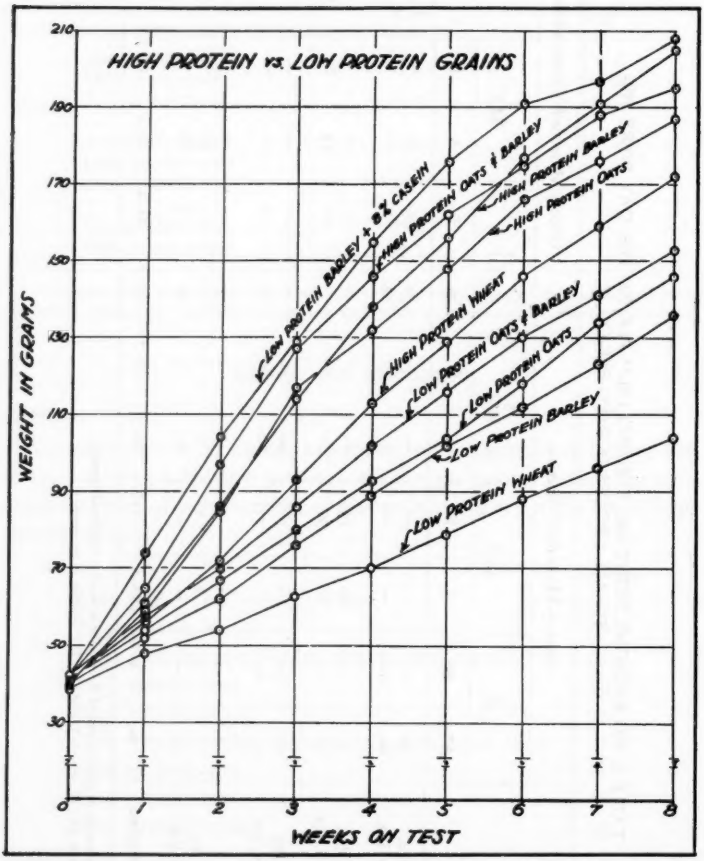

Figure 1. Growth curves for groups of six weanling rats fed grains of markedly different protein content.

Pigs

A summary of the results of a pig feeding trial in which the basal grain rations were formulated with mixtures of oats and barley of markedly different protein content (see table 1) is presented in table 3.

TABLE 3. LOW, MEDIUM AND HIGH PROTEIN GRAINS FOR PIGS

Items compared	1	2	3	4	5	6
	Grain+mineral +vitamins			Grain+mineral +vitamins+protein		
	L.P.	M.P.	H.P.	L.P.	M.P.	H.P.
Mean protein in ration, percent	9.2	12.6	16.6	12.2	15.3	19.1
Percent from:						
Grain	100	100	100	71	77	81
Mixed supplement	—	—	—	29	23	19
No. pigs in lot	7	7	7	7	7	6*
Av. no. days on expt.	189	172	157	145	146	138.8
Av. initial wt., lbs.	30.4	31.0	31.6	30.6	31.1	31.3
Av. final wt., lbs.	195.6	198.3	200.1	201.0	206.7	204.5
Total gain, lbs.	1156	1171	1180	1193	1229	1040
Av. daily gain, lbs.	0.87	0.97	1.07	1.17	1.20	1.25
Av. daily feed, lbs.	4.25	3.94	4.07	4.19	4.08	4.35
Feed required for 100 lbs. gain:						
Grain, lbs.	476.8	397.1	372.0	327.3	312.0	318.7
Mixed supp., lbs.	—	—	—	29.8	27.2	29.6
Ground limestone and iodized salt, equal parts, lbs.	9.7	8.1	7.6	—	—	—
Total, lbs.	486.5	405.2	379.6	357.1	339.2	348.3

* 7 pigs initially—1 pig died early in the course of the experiment. Feed estimated to have been consumed by the pig was deducted from the total.

Comparison of the results shown in this table for pigs in lots 1, 2 and 3 in which a mixture of oats and barley constituted the only source of protein in the ration shows that, under these conditions, the protein content of the grain has a marked influence on the rate and economy of gain. The average daily gain increased by increments of 0.1 pound from the low to the medium to the high protein grain groups. The pigs fed high protein grain put on 100 lbs. gain with 26 lbs. less feed than did those fed medium protein grain and at a saving of 107 lbs. of feed as compared to pigs fed low protein oats and barley. It will, however, be noted that the pigs in group 4, fed a ration containing 12.2% protein, 71% of which came from grain and 29% from a tankage-fish meal-linseed oil meal supplement, made more rapid gains and more efficient use of their feed than did the pigs in lot 3 which were fed a ration containing 16.6% protein of grain origin. These, and other results summarized in table 3, are in agreement with the established fact that grain proteins are lacking in quality for the promotion of efficient growth in swine.

Reference to the results for lots 4, 5 and 6 shows that there were no marked differences between these lots, which suggests that when protein supplement is added at the levels used in this experiment, the protein content of the grain may have comparatively little effect on the growth of pigs. It may be noted that the rate of gain was lower and the feed required per

100 lbs. gain was higher in lot 4, fed low protein grains, than in either lot 5 or 6, fed medium and high protein grains respectively, but the differences are small and further trials are required to show whether they are significant.

Inspection of the figures given in table 3 for feed required to produce 100 pounds gain in the different groups shows that when the mixed protein-mineral supplement was used at an arbitrary level, without regard to the protein content of the grains, marked differences resulted in the saving in feed attributable to the use of the supplement. Thus, when fed with grains averaging 9.2 percent in protein content, one pound of supplement replaced 5 pounds of grain (lot 4 *vs.* lot 1), but when fed at the same level with 12.6 and 16.6 percent protein grains the grain equivalent of a pound of supplement was reduced to 3.1 and 1.8 pounds respectively. Such results indicate that protein supplements may be especially valuable to swine producers located in areas where the protein content of grains is relatively low. Additional experiments are required to study possibilities in the way of effecting more economical use of available supplies of protein supplements through adjustment of levels of supplementation with reference to the protein content of the grains in the basal ration.

Summary

Feeding trials were conducted with rats and pigs to compare the rates of gain of groups of animals fed cereal grains of different protein content. Oats, barley and wheat grown under diverse conditions of soil and climate were used. The crude protein content of these grains ranged from a minimum of 8.2 to a maximum of 17.3 percent. Marked differences, attributable to variations in the protein content of the grains, were observed in the growth response of both rats and pigs. On the basis of the results obtained, it is suggested that more detailed experimentation in this field may be of value in achieving more efficient use of protein supplements in swine rations, especially in areas where the level of protein in the grains available differs markedly from the general average for the protein content of such grains.

Literature Cited

Anderson, J. A. 1939–1941. Thirteenth, Fourteenth and Fifteenth Annual Reports of the Grain Research Laboratory, Board of Grain Commissioners for Canada, Winnipeg, Manitoba.

Anderson, J. A. and T. R. Aitken. 1943–1946. Seventeenth, Eighteenth, Nineteenth and Twentieth Annual Reports of the Board of Grain Commissioners for Canada, Winnipeg, Manitoba.

McCollum, E. V., V. Simmonds and W. Pitz. 1916. The Relation of the Unidentified Dietary Factors, the Fat-soluble A, and Water-soluble B, of the Diet to the Growth Promoting Properties of Milk. Jour. Biol. Chem. 27: 33–43.

CRYSTALLINE OR CRUDE CONCENTRATES OF B-VITAMINS SUPPLEMENT A CORN-SOYBEAN MEAL RATION FOR WEANLING PIGS IN DRYLOT[1]

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University of Illinois[3]

SINCE 1943, workers at the Illinois Station have been studying the nature of the deficiencies of a ration composed chiefly of corn and soybean meal with essential fat-soluble vitamins and minerals added for weanling pigs continuously fed in drylot. The basal ration contained 20% total protein and was composed of ground yellow corn 52%, wheat flour midlings 15%, expeller soybean meal 30.5%, fortified vitamin A and D oil 0.5% and minerals 2%.

Although this ration was improved for weanling pigs by the addition of the six crystalline B-vitamins (B_1, B_2, B_6, pantothenic acid, niacin and choline), optimum growth was still not obtained (Krider *et al.*, 1943, Fairbanks *et al.*, 1944). The B-vitamins were added to supply amounts in excess of the pig's known requirements, or at the rate of 150 mg. thiamin, 150 mg. riboflavin, 500 mg. niacin, 600 mg. pantothenic acid, 250 mg. pyridoxine and 150 grams choline chloride per 100 pounds of the ration. Fairbanks, Krider and Catron (1944) reported that 6% distillers' solubles or 10% alfalfa meal supplemented such a plant protein basal ration, but growth rates were still subnormal even with these supplements added. Furthermore, their experiments indicated that the inclusion of animal proteins (tankage and fishmeal) along with plant proteins in otherwise complete rations for weanling pigs confined in drylot from birth increased growth rates and markedly reduced death losses, compared with results obtained when pigs received only plant protein supplements. The animal protein feeds were considered to be of value chiefly because of their vitamin content.

Later experiments (Krider, Fairbanks and Carroll, 1944) showed that the plant-type basal ration (6 B-vitamins included) containing 20% total protein

[1] These investigations were supported by the donation of funds and products to the University of Illinois by the A. E. Staley Manufacturing Company, Decatur, Illinois. The dehydrated alfalfa meal was kindly supplied by Ralston Purina Company, St. Louis, Missouri.

[2] Acknowledgment is gratefully made to R. H. McDade, Chief Swine Herdsman, and his associates for their cooperation. We are grateful to Dr. D. F. Green and Merck and Company, Rahway, New Jersey, for supplying pyracin, biotin, inositol and para-aminobenzoic acid. The cooperation of Dr. T. H. Jukes, Dr. E. L. R. Stokstad and Lederle Laboratories, Pearl River, New York, in making suggestions and donating the AB liver extract, pteroylglutamic acid, folic acid concentrate, choline chloride, thiamin, riboflavin, niacin, pantothenic acid and pyridoxine is gratefully acknowledged. The vitamin K and alpha tocopherol were obtained through the courtesy of Dr. J. C. Bauerenfiend and Hoffmann-La Roche, Nutley, New Jersey.

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was not lacking in quantity of protein. In a paired-feeding test (equal feed) 0.3% dl-methionine did not improve the rate or economy of gains of ten pairs of weanling pigs fed the above basal ration plus the 6 crystalline B-vitamins and 1.5% AB liver extract which was added to eliminate the probability of a deficiency of the unknown factor (s) (Illinois Station, unpublished data).

In a group-feeding experiment (Illinois Station, unpublished data) evidence was obtained indicating that the essential growth factor(s) was supplied in suboptimum, but in significant amounts by 10% "vitamin-free" casein. The addition of 1.5% AB liver extract or 10% dehydrated alfalfa meal to the ration containing the 6 B-vitamins and 10% "vitamin-free" casein further improved the growth rates, indicating that these supplements were contributing significant amounts of the essential unknown factor(s). In the experiment, all rations were equated to contain 20 percent total protein. Ten weanling pigs were fed in each group. The rations fed and average daily gains per pig from weaning to 100 pounds were as follows:

Ration	Av. daily gain per pig
1. Basal ration plus 6 B-vitamins	0.76 lbs.
2. Same as 1 plus 10% "vitamin-free" casein	0.93 lbs.[4]
3. Same as 2 plus 1.5% AB liver extract	1.01 lbs.[4]
4. Same as 2 plus 6% dried corn distillers' solubles	0.84 lbs.
5. Same as 2 plus 10% dehydrated alfalfa meal	0.99 lbs.[4]

These results with pigs are in agreement with those obtained with rats by Cary and Hartman (1947). They reported that commercial "vitamin-free" casein, liver extracts and alfalfa hays contain an unidentified factor which is essential for normal growth and reproduction of rats while yellow corn, wheat flour and bran, and soybean meal do not contain the unidentified factor X (Hartman *et al.*, 1946).

Experimental Procedure

During 1945–46–47, three series of tests have been completed to study further the nature of the vitamin deficiencies of the plant-protein-basal ration for weanling spring pigs fed in drylot. The tests will be referred to as experiments C, B and A, respectively. All rations were adjusted to contain 20% total protein when supplemental feeds containing protein were added.

Basal Rations

The ingredients and composition of the basal rations fed are given in table 1.

[4] Highly significant over average daily gain of Lot 1 ($P \leqq 0.01$).

TABLE 1. COMPOSITION OF BASAL RATIONS FED

Ingredients	Expt. A	Expts. B and C
Ground yellow corn, percent	63.5	52.0
Soybean meal, expeller,[1] percent	34.0	30.5
Wheat flour middlings, percent	—	15.0
Fortified vitamin A and D oil,[2] percent	0.5	0.5
Mineral mixture (H & K),[3] percent	2.0	2.0
Total	100.0	100.0
Total protein, percent	20.0	20.0
Calcium, percent	.58	.58
Phosphorus, percent	.51	.54
Manganese, p.p.m.	43.0	56.0

[1] Kindly supplied by the A. E. Staley Manufacturing Company, Decatur, Illinois.
[2] Guaranteed to contain 2000 I.U. of vitamin A and 400 U.S.P. units of vitamin D per gram.
[3] Mineral mixture reported by Krider *et al.* (1946), JOURNAL OF ANIMAL SCIENCE 5(3). 256–263.

Supplemental Ingredients

When the 6 crystalline B-vitamins were fed, they were added to supply approximately double the established requirements of the pig, or at the rate of 150 mg. thiamin, 150 mg. riboflavin, 500 mg. niacin, 600 mg. pantothenic acid, 250 mg. pyridoxine and 150 grams choline chloride per 100 pounds of the ration.

The dehydrated alfalfa meal fed contained the following nutrients according to chemical analyses and vitamin assays:

	Expt. A	Expt. B	Expt. C
Total protein, %	17.9	19.5	17.1
Crude fiber, %	21.6	23.8	27.8
Carotene, mg. per lb.	122.1	104.4	32.7
Riboflavin, mg. per lb.	7.4	6.9	6.7

The AB liver extract contained 45% total protein and 0.8–1.0 mg. of the L. casei factor per gram.[5]

The young dried cereal grass (Cerogras) contained 22.9% total protein.[6]

Previous History of the Pigs

The weanling pigs used in experiment B were raised by sows fed in the drylot experiments described by Krider, Van Poucke, Becker and Carroll (1946). The pigs used in experiment A had a previous nutritional history

[5] Prepared and supplied by Lederle Laboratories, Pearl River, New York.
[6] Donated by Cerophyll Laboratories, Kansas City, Missouri.

similar to those used in experiment B. Only pigs from sows that had given satisfactory gestation-lactation performance on presumably adequate rations were used. The dams and grandams of the pigs had been kept in drylot continuously since birth. Nevertheless, it is believed that all pigs used did have some "vitamin reserves" when they were placed on these growth experiments.

The pigs used in experiment C were from sows confined in drylot from breeding. The gestation-lactation results were reported by Krider *et al.* (1946*a*). These pigs were also considered to be in a good state of nutrition when started on test.

Results and Discussion

In table 2 the results of supplementing the basal ration for the weanling spring pigs in drylot are briefly summarized. All pigs were kept on concrete feeding floors.

The pigs in experiment A were started on test May 9 and continued to thrive on the unsupplemented basal ration (lot 1) until after June 26. During the next 18 days the pigs became emaciated, unthrifty, coarse and rough in hair coat, and all developed a severe diarrhea (figure 1). The pig mortality rate in this lot was approximately 27 percent. Blood analyses from the 8 surviving basal pigs on July 21 showed an average of 7.0 grams of hemoglobin per 100 cc. of blood and 5.1 million red blood corpuscles per c. mm. Blood samples from pigs in Lots 2 (4 pigs), 3 (3 pigs), 4 (5 pigs) showed hemoglobin values of 10.0, 10.3, and 9.8 grams per 100 cc., and red blood corpuscle counts of 6.9, 6.7, and 7.1 million per c.mm., respectively. The average white blood cell counts per c.mm. of blood were (lot 1) 44,812, (lot 2) 27,000, (lot 3) 24,333, and (lot 4) 20,800.

Two pigs in poor condition (lot 1) were killed on August 1. Histological sections were made from the kidney, liver, spleen, pancreas and thigh muscle of each pig. The kidneys and livers were pathological. The tubules near the surface of the kidneys were abnormal showing enlarged cells which were either vacuolated or reticulated. The livers showed much evidence of fatty infiltration and areas with unusual amounts of connective tissue. Large accumulations of lymphocytes also were seen in the sinusoids and in the blood vessels.

Discussion

Apparently the basal ration is deficient in one or more of the 6 B-vitamins which were added (B_1, B_2, B_6, pantothenic acid, niacin and choline) since growth rate was significantly improved. However, growth rate was still suboptimum when these were added. Further tests are in progress to learn

TABLE 2. RESULTS OF SUPPLEMENTING THE BASAL RATIONS
ALL RATIONS CONTAINED 20% TOTAL PROTEIN

Experiment, lot number and treatment	Items Compared					
	No. Pigs	Av. initial weight, lbs.	Av. final weight, lbs.	Av. daily ration, lbs.	Av. daily gain, lbs.	Feed eaten per 100 lbs. gain, lbs.
Experiment A						
1. Basal ration	11[1]	32	54	1.29	.30	444
2. Same as 1+6 B-vitamins	12	33	76	2.52	.94**	279
3. Same as 2+10% dehydrated alfalfa meal	12	33	75	2.40	.80**	307
4. Same as 2+0.5 mg. PGA (pteroylglutamic acid or folic acid) per lb. of ration	12	33	75	2.33	.89**	269
Experiment B						
1. Basal ration+6 B-vitamins	13	32	75	2.57	.98	266
2. Same as 1+10% dehydrated alfalfa meal	13	32	75	2.52	.90	285
3. Same as 1+1.5% AB liver extract	13	32	75	2.74	1.08*	256
4. Same as 1+0.24 mg. PGA per lb. of ration	13	32	76	2.62	1.05	252
Experiment C						
1. Basal ration+6 B-vitamins	10	32	78	2.65	1.12	246
2. Same as 1+other crystalline vitamins (pyracin, PABA, inositol, biotin, E & K)[2]	10	33	77	2.69	1.06	262
3. Same as 1+10% dehydrated alfalfa meal	10	34	75	2.50	1.00	264
4. Same as 1+1.5% AB liver extract	10	34	77	2.91	1.22*	244
5. Same as 1+folic acid concentrate (to supply .24 mg. PGA per lb. of ration)	10	34	75	2.85	1.09	270
6. Same as 1+5% Cerogras	10	33	76	2.70	1.11	253

[1] 3 pigs did not complete the test.

* Significantly more rapid average daily gain than obtained in Lot 1 ($P \leq 0.05$).

** Highly significant over average daily gain of Lot 1 ($P \leq 0.01$).

[2] Other crystalline vitamins added in the following amounts per 100 lbs. of ration: 125 mg. pyracin, 13.6 gms. PABA (para-aminobenzoic acid), 45.4 gms. inositol, 20 mg. biotin; 280 mg. alpha tocopherol and 40 mg. vitamin K.

which vitamin (or vitamins) of the B-complex group is responsible for the growth response.

Although the inclusion of 10% dehydrated alfalfa meal in the basal ration plus the 6 B-vitamins did not increase the average daily gains, the pigs so fed had sleeker hair coats, and fewer abnormalities of feet, legs and gaits. In tests not reported in this paper, the gilts retained from the lots receiving the

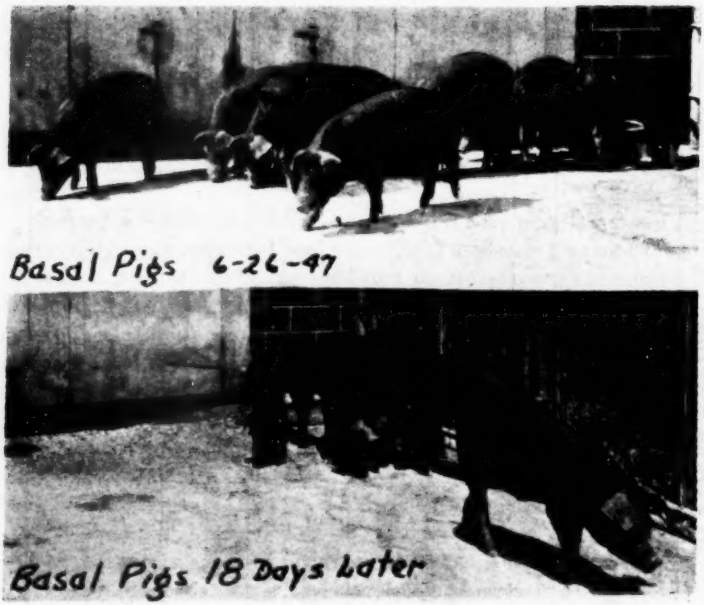

Figure 1. The top photo shows the basal pigs 48 days after they were placed on test. The lower photo shows the same pigs 18 days later.

alfalfa meal have consistently shown much better breeding, gestation and lactation performance than gilts fed the basal ration plus the 6 B-vitamins.

For optimum growth of weanling pigs, AB liver extract contains an unidentified nutrient. The basal ration plus the 6 B-vitamins was significantly improved by the addition of 1.5% AB liver extract. The addition of PGA (pteroylglutamic acid), pyracin, biotin, inositol, PABA (para-aminobenzoic acid), alpha tocopherol and vitamin K to the basal ration plus the 6 B-vitamins did not significantly improve performance, indicating that these nutrients

were not the same as the unidentified nutrient(s) contained in the AB liver extract, and that these vitamins either (1) were not lacking in the basal ration, (2) were not required, or (3) were synthesized by the pig at a sufficiently rapid rate to meet its needs. Lindley and Cunha (1946) showed that biotin and inositol were needed by the pig when sulfathalidine was included in a purified ration. Cunha *et al.* (1947) reported that no beneficial effect on growth, efficiency of feed utilization or external appearance was obtained when either PABA or PGA was added alone or together with inositol or biotin to a purified diet containing the 6 B-complex vitamins (B_1, B_2, B_6, niacin, pantothenic acid and choline).

Evidence obtained in our earlier experiments indicates that the unidentified factor is also present in commercial "vitamin-free" casein (unpublished data). These results indicate that the unidentified factor which is needed for optimum growth of pigs may be similar to nutrient X reported by Hartman *et al.* (1946) to be essential for rat growth.

Summary and Conclusions

Weanling pigs from sows kept in drylot were fed to weights of 75 pounds. In test A, the basal ration contained 63.5% ground yellow corn, 34% ex eller soybean meal, 0.5% fortified vitamin A and D oil, and 2% of a complex mineral mixture. In tests B and C, 15% of wheat flour middlings replaced part of the corn and soybean meal. All rations fed were formulated to contain 20% total protein.

The addition of the 6 crystalline B-vitamins (B_1, B_2, B_6, niacin, pantothenic acid, and choline) to the basal ration significantly improved survival, growth rate, red blood corpuscle counts, and hemoglobin values of the pigs. However, this supplementation produced suboptimum growth rates. When 1.5% AB liver extract was added to the basal ration plus the 6 B-vitamins, the average daily gains were significantly increased. Ten percent of dehydrated alfalfa meal added to the basal ration plus the 6 B-vitamins did not increase the rate of gains but pigs so fed showed sleeker hair coats, and fewer abnormalities of feet, legs and gaits.

Further studies showed that the basal ration with B_1, B_2, B_6, niacin, pantothenic acid and choline added was not deficient in biotin, pyracin, inositol, para-aminobenzoic acid (PABA), pteroylglutamic acid (PGA), alpha tocopherol or vitamin K. Since these vitamin additions did not produce results comparable to those obtained by adding 1.5% AB liver extract under the described feeding conditions, it is concluded that the latter product contains a factor(s) which is required for optimum growth of young pigs. The growth factor(s) in the AB liver extract is not identical to the various crystalline vitamins tested.

Literature Cited

Cary, C. A. and A. M. Hartman. 1947. Unidentified Nutrients. U.S.D.A. Yearbook of Agriculture 1943–47, pp. 779–786.

Cunha, T. J., L. K. Bustad, W. E. Ham, D. R. Cordy, E. C. McCulloch, I. F. Woods, G. H. Conner and M. A. McGregor. 1947. Folic Acid, Para-aminobenzoic Acid and Anti-pernicious Anemia Liver Extract in Swine Nutrition. Jour. Nutrition 34: 173–187.

Fairbanks, B. W., J. L. Krider and D. Catron. 1944. Some Observations on Plant Versus Animal Protein Supplements for Young Pigs. North Amer. Vet. 25: 351–355.

Hartman, A. M., L. P. Dryden, G. D. Likely and C. A. Carey. 1946. An Unidentified Nutrient in Foods and Feeds. JOURNAL OF ANIMAL SCIENCE 5: 404–405.

Krider, J. L., B. W. Fairbanks, D. Catron and W. E. Carroll. 1943. Vegetable Versus Animal Protein Supplements for Young Pigs. JOURNAL OF ANIMAL SCIENCE 2: 367.

Krider, J. L., B. W. Fairbanks and W. E. Carroll. 1944. The Nature of the Deficiencies of an All-Plant Ration for Weanling Pigs in Drylot. JOURNAL OF ANIMAL SCIENCE 3: 454.

Krider, J. L., R. F. Van Poucke, D. E. Becker and W. E. Carroll. 1946. Preliminary Studies on Supplementing a Ration for Brood Sows with Folic Acid, Vitamins, and Vitamin Concentrates. JOURNAL OF ANIMAL SCIENCE 5: 406.

Krider, J. L., B. W. Fairbanks, R. F. Van Poucke, D. E. Becker and W. E. Carroll. 1946*a*. Sardine Condensed Fish Solubles and Rye Pasture for Sows During Gestation and Lactation. JOURNAL OF ANIMAL SCIENCE 5: 256–263.

Lindley, D.C. and T. J. Cunha. 1946. Nutritional Significance of Inositol and Biotin for the Pig. Jour. Nutrition 32: 47.

THE STORAGE OF DDT IN THE TISSUES OF PIGS FED BEEF CONTAINING THIS COMPOUND

R. H. Carter,[1] P. E. Hubanks,[1] H. D. Mann,[1] J. H. Zeller,[2] and O. G. Hankins[2]

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Feeding experiments to determine the absorption and storage of DDT in the tissues of pigs receiving small amounts of this compound in their diet were carried out. Beef from the carcasses of three steers which had been fed for a number of months on hay containing DDT residues, and of two calves which had been raised on milk from cows on similar feed, was used as a supplement to corn meal in these tests.

The carcasses of these steers and calves were boned separately and the meat and fat from each was finely ground and composited except for several pieces from one animal which were set aside for cooking tests (Carter *et al.*, 1948). Samples of the composites were subjected to chemical analysis for their DDT content, which was determined by the Schechter-Haller colorimetric method modified for use on this kind of material (Schechter, Pogorelskin and Haller, 1947). The ground meat was mixed with an equal weight of anhydrous sodium sulfate and, after drying at 70°–80° C. in an air drier for 12 to 16 hours, was extracted with benzene for several hours at room temperature. An aliquot of the solution was then filtered and analyzed. The results of the chemical analyses and other pertinent data are given in table 1.

TABLE 1. DDT CONTENT OF MEAT FROM BOVINES RECEIVING THIS COMPOUND IN THEIR DIET

Weight of animal when slaughtered, pounds	Weight of bones and meat, pounds	Weight of meat, pounds	DDT content of hay, p.p.m.	DDT content of meat, p.p.m.
Meat from steers				
610	279	215	184	20
570	193	144	184	16
740	204	163	48	11
Meat from calves				
260	74	53	—	24
150	66	44	—	19

[1] Bureau of Entomology and Plant Quarantine.

[2] Bureau of Animal Industry.

The ground meat from these five animals was divided into two portions, one consisting of 312 pounds with a weighted average DDT content of 20.2 p.p.m., the other 307 pounds with a weighted average DDT content of 13.3 p.p.m. Each portion was mixed with corn meal in the ratio of 1 part to 3 so that the two portions contained 5 and 3 p.p.m. of DDT, respectively.

Two lots of six pigs each, fall 1946 farrow, were fed this material for 36 days from January 6 to February 11, 1947, in amounts slightly under a full diet. Data pertaining to the different lots of pigs are tabulated below (figures in pounds):

Item compared	Lot 1	Lot 2
Average weight of pigs		
At beginning of test	84.0	83.3
At end of test	127.2	128.1
Cornmeal in diet	714.9	714.9
Ground beef in diet	237.7	237.7
DDT content of diet	5 p.p.m.	3 p.p.m.
Amount of food consumed per 100-pound gain	367.8	354.11

The pigs were slaughtered on February 12, and the carcasses were separated into lean meat, leaf fat, and external with intermuscular fat. One sample of each material was taken from each lot after it had been ground and thoroughly mixed. The DDT was determined by the colorimetric method previously referred to. The results are given in table 2.

TABLE 2. DDT CONTENT OF MEAT AND FAT FROM PIGS FED BEEF CONTAINING THIS COMPOUND

Material	Weight, pounds		DDT, p.p.m.	
	Lot 1	Lot 2	Lot 1	Lot 2
Lean meat	231.9	238.5	2.0	1.7
External with intermuscular fat	152.9	155.1	15.6	11.4
Leaf fat	13.9	11.2	17.6	14.6

The total DDT accounted for was 1.406 grams in lot 1 and 1.059 in lot 2. The results showed that 49 to 57 percent of the DDT taken into the pigs was recovered in the fat and muscle portions. In both lots the highest concentration of DDT was found in the leaf fat, and the lowest concentration in the lean meat.

Literature Cited

Schechter, M. S., M. A. Pogorelskin and H. L. Haller. 1947. Colorimetric determination of DDT in Milk and Fatty Materials. Analyt. Chem .19: 52–53.

Carter, R. H., P. E. Hubanks, H. D. Mann, Lucy M. Alexander and Grace E. Schopmeyer. 1948. The Effect of Cooking on the DDT Content of Beef. Science 107: (2779) pp. 347–349.

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE FORTIETH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Hotel Sherman in Chicago on November 26 and 27, 1948, with a dinner for the honor guest on November 28.

Breeding and Genetics Section

A. B. Chapman, *Chairman*

PREDICTING LIVE NORMAL SPERM IN RAMS FROM MOTILITY SCORES. L. Otis Emik, Clair E. Terrill and Geo. M. Sidwell, *United States Department of Agriculture.*

The object was to determine the reliability of using visual estimates of motility to predict the percent of live normal sperm as counted on opal blue and eosin stained smears. 1140 ejaculates were analyzed from 428 ram trials of 30 minutes using Rambouillet, Columbia, Targhee and Corriedale rams over a period of three years. Percentages were transformed to angles and the regression of motility on live normal sperm calculated. An empirical transformation and combination of motility percentage and score gave a nearly perfect fit. This latter transformation was then reapplied to the original data and a second analysis was made. The correlation was .89 for rams which is highly significant. Means for years showed an improvement with time which was to be expected from the improvements being made in management of the rams. Breed differences were significant, while the number of ejaculates per trial and the positional order of the ejaculate had no effect on means. In general, visual estimates were more variable than counts from slides. The repeatability of visual estimate and counts were nearly identical at 0.8, which is highly significant.

PRODUCTION OF A BACON TYPE HOG SUITABLE TO THE FEED AND CLIMATIC CONDITIONS OF THE PACIFIC NORTHWEST. M. E. Ensminger, H. H. Brugman and R. F. Johnson, *Washington State College.*

The line, hereafter referred to as Proj. No. 61 hogs, was started in 1945 at the State College of Washington, and is based on a crossbred foundation of 5 Danish Landrace boars and 18 Chester White females. Three Landrace boars and 13 Chester White females have contributed to the present breeding herd. The herd has been bred entirely from within.

The primary objective has been the development of a superior meat type of hog, with carcass studies used as a guide. Carcass measurements taken include percentage of the 5 primal cuts, total lard (back fat, plate lard, leaf lard), length, average thickness of backfat. All percentages are based on cold weight. A photograph is taken of the cross section at the first rib of one side of the carcass, the loin area is measured with a planometer and the bacon rasher is graded. Selection has also been rigorous for such economic factors as fertility, survival, rate of gain and economy of gain. Performance has been maintained, although the average Fx of the 1948 litters is 14.2%. Carcasses are longer and of a more desirable bacon type than the Chester White control lots. An analysis of the overall breeds champion carload lot of 26 Proj. No. 61 and 24 Duroc Jersey reserve champion barrows at the 1947 Pacific International showed that the Proj. No. 61 barrows weighed on the average 220 lbs., yielded 5% more primal cuts, and had 26% less backfat than the Duroc Jerseys which weighed 42 lbs. less.

THE SIMILARITIES OF IDENTICAL CATTLE TWINS WITH REFERENCE TO GROWTH AND BLOOD COMPOSITION Lester O. Gilmore, W. E. Petersen, J. B. Fitch and D. L. Hill, *University of Minnesota.*

The successful use of the polysomatic diagnosis of similarity depends upon a large num-

ber of characters of known inheritance. The characters now available about which something is known of their inheritance are sex, color, color pattern, physical characters, and temperament. The physical characters include facial features, ear size and shape, contour of neck, top line, tail head, tail, legs, pasterns, body proportions, hair growth, hair pattern (whorls—number, direction, location—escutcheon) and nose prints. Color patterns appear to have the greatest somatic variation. The presence of mirror imaging represents late cleavage and is additional evidence of monozygosity. A comparison of performance in growth, production, fattening and blood analysis for antigens and composition is valuable but usually not possible in field diagnosis. They do constitute a valuable check on the original diagnosis and also furnish needed data on the relative influence of heredity and environment. The charts presented show the greater similarity of growth as measured by height at withers and body weight between twins as compared to stable mates of comparable age some of which are closely related. The twins were fed similarly before being purchased. Subsequently they all were placed on the same feeding plan of good alfalfa hay, ad libitum, and limited milk and grain. The charts show the greater similarity of hemoglobin values within twin pairs as compared to values between twin pairs. Other blood constituents are being determined.

SOME STRAIN AND INBREEDING DIFFERENCES IN GROSS TESTICULAR DEVELOPMENT OF SWINE. E. R. Hauser and G. E. Dickerson, *University of Missouri.*

In studying inbreeding and strain differences in boar performance, gross measurements of the testis are being made on boars of three inbred lines and their crosses. Poland China lines II and VI and Hampshire line V are about 50, 25 and 25 percent inbred, respectively. To obtain maximum information from boars available, unilateral castrations were performed at ten-day intervals from 125 to 175 days of age. The testis proper and epidymus were separated. Data indicate compensatory growth of the remaining testis at ages over five months. Testes were approximately half as large in line II as in line V and VI boars, at ages studied. In boars castrated at about 100 days of age, testes of line VI boars were larger than those of line V; at 125 and 135 days of age there was no difference; but beginning at 145 days the testes of the line V boars were larger. Epidymi were about two-thirds as large in the two Poland lines as in the Hampshire line, being especially small relative to testis size in line VI. Testes were shorter and thicker in the Hampshire than in the Poland lines. Limited data on linecross boars gave no suggestion of heterosis in testis size up to 155 days of age. Testes were smaller in both line II inbreds and II×V linecrosses than in line VI inbreds and VI×V linecrosses, suggesting that small testis size is characteristic of line II rather than a result of its higher inbreeding.

COMPARISONS OF INBRED POLAND CHINA, LANDRACE AND PUREBRED BOARS ON IOWA FARMS. L. N. Hazel, A. L. Musson and Jay L. Lush, *Iowa State College.*

Swine management practices and incidence of disease vary widely from farm to farm. The most efficient experimental design for studying genetic differences is to balance farm differences by using two or more boars on each farm. The design becomes more efficient as the number of boars per farm is increased. At levels of inbreeding from 30 to 50%, little accuracy is gained by having more than 10 litters per inbred boar. Farrowing records, weaning weights, and five-month weights have been obtained for more than 800 litters on 50 farms where inbred Poland China, Landrace, or purebred boars were compared. There is considerable variability in results with the inbred Poland boars, a part of which is due to genetic differences between the several lines involved. Eighty percent of the pigs farrowed alive have lived to five months of age, at which time they weighed 132 pounds. The average difference of 2% in viability and one pound in five-month weight in favor of pigs sired by inbred Poland boars over those sired by purebred boars is too small to be statistically significant or economically important. The results with the Landrace boars are much more consistent. The average superiority of their pigs over those of purebred boars is 3.5% in viability and 12 pounds in five-month weight. This may be a manifestation of heterosis due to the genetic diversity between

Landrace boars and sows of American breeding, rather than directly to genetic superiority of the Landrace.

BIRTH WEIGHTS AND AVERAGE DAILY GAINS IN HOTHOUSE LAMB PRODUCTION. William L. Henning and Glenn R. Kean, *The Pennsylvania State College.*

This study was a comparison of birth weights and average daily gains on ten different kinds of breeding used in hothouse lamb production and indicates that the (Dorset × Corriedale-Merino) cross is the heaviest at birth and makes the most rapid gains of all lambs studied. This cross also had a very high percentage of high quality carcasses. The study showed that the three-breed crosses are more desirable than the two-breed crosses. It was found, also, that the purebred Hampshire lambs compare very favorably with the three-breed crosses. The three mutton type rams studied in the report rank, in order, Dorset, Hampshire, and Southdown. It was found that from the 882 lambs of 10 crosses, the average birth weight was 8.5 pounds. The average birth weight of all males, 456, was 8.9 pounds; 426 females, 8.3 pounds; 338 twins, 7.7 pounds; and 524 singles averaged 9.1 pounds. From the same population of 822 lambs there were 52 males to 48 females, while there were 41 twins to 59 single births. The average daily gain of 787 lambs was 0.53 pound per day. The average daily gain of 423 males was 0.54 pound; 364 females, 0.51 pound; 317 twins, 0.45 pound; and 443 singles averaged 0.60 pound per day. The results show that there tends to be a correlation between birth weights and average daily gains in lambs of the breeds and crosses studied in this experiment.

RELATIONSHIP BETWEEN CERTAIN BODY MEASUREMENTS AND YIELD OF FIVE PREFERRED CUTS IN SWINE. H. O. Hetzer, O. G. Hankins, J. X. King and J. H. Zeller, *U. S. Department of Agriculture.*

This study was undertaken to determine the reliability of using live body measurements in estimating the percentage yield of ham, loin, bacon, shoulder and butt. A total of 141 pigs representing six inbred strains and all possible crosses among these strains were used. Two measurements by each of two men were secured for all pigs at about 225 pounds for length and height, width and depth of middle, width at shoulders, width at hams, and depth and circumference at chest. The averages for these measurements were then used in a multiple correlation and regression analysis, using both the yield of trimmed and untrimmed cuts as dependent variables. Width of middle was found to have the greatest predictive value for estimating yield of trimmed cuts, followed by height and depth of middle. Narrower, taller and shallower animals tended to yield a higher proportion of the five cuts than those which were below average for these items. Width at hams had a considerably lower predictive value, while length, width at shoulders, and depth and circumference at chest showed practically no relationship with yield of trimmed cuts. Height and depth of middle were about as reliable in estimating yield of untrimmed cuts as for trimmed cuts. Width at shoulders showed some predictive value, but was not so reliable as height, or depth of middle. Width of middle, length, width at hams, depth and circumference at chest, on the other hand, showed practically no relationship with yield of untrimmed cuts. Although certain body measurements showed a definite relationship with yield, their usefulness was rather limited.

SELECTION IN INBRED LINES OF SWINE. Roy M. Kottman, Jay L. Lush and L. N. Hazel, *Iowa State College.*

The Iowa Station has maintained eight one-sire lines and three two-sire lines of Poland China swine since 1938. A four-sire line has been carried since 1930. These lines have been closed to outside blood since their inception, and inbreeding coefficients have increased at varying rates depending upon the number of sires used. Levels of performance for number of pigs farrowed and weaned, and for individual weights at 56 and 154 days have declined as inbreeding increased. The selection differentials (the average performance of parents minus the average of all animals in their generations) have been determined for all lines since the founda-

tion of each. Differences in the size of selection differentials in the one- two-, and four-sire lines are small. The annual selection differentials averaged about one-fourth pig per litter at birth, one-half pig per litter at weaning, and 18 pounds in individual pig weight at 154 days for the entire period. Sizes of the selection differentials were larger in the later years of the experiment than in the early years. The average age of parents varied from 1.3 to 1.43 years in these lines as compared with 2.5 years for Poland China swine in breeders' herds. Selection differentials were larger for sires than for dams. The theoretical improvement expected in each line was computed using the selection differentials, estimates of heritability, and decline due to inbreeding. Present levels of performance in these lines are in general below those expected when allowance is made for decline due to inbreeding, and for the theoretical improvement due to selection.

EXPERIMENTAL CHECK OF THE EFFECTIVENESS OF SELECTION FOR A QUANTITATIVE CHARACTER. W. H. Kyle and A. B. Chapman, *University of Wisconsin.*

Theoretically it is possible to predict the average of the offspring of selected parents provided the selection intensity and heritability of a character are known. Predictions of this sort have not, however, been extensively checked experimentally. This report deals with an experiment designed to check the expected outcome against observed results of selection for a quantitative character in animals. The character studied was the response of the immature rat ovary to a gonadotrophic hormone. An estimate of heritability was obtained from rats in the foundation colony. Selections for high and for low ovarian response were made on the basis of full-sister and progeny information. A part of each group which was being selected for high and low ovarian response was maintained without inbreeding, while in the remainder of the group selection was combined with an inbreeding program. More than six hundred litters from unselected parents and one thousand litters from selected parents produced over a seven-year period constitute the data for this analysis. The accuracy of predictions made on the basis of theoretical considerations will be indicated.

EFFECT OF SEASON UPON SPERMATOGENESIS AND FERTILITY OF DAIRY BULLS UNDER MICHIGAN CONDITIONS. Robert C. Lewis, *Michigan State College.*

An analysis of nearly three years' semen collection and breeding records of the Holstein and Guernsey bull studs of the Michigan Artificial Breeders' Association has been made in an effort to determine the effect of seasonal variations in light and temperature upon spermatogenesis and fertility. A comparison was also made between spermatogenesis and fertility of the two breeds. The Holstein bulls surpassed the Guernseys in spermatozoa concentration, total spermatozoa and initial motility. The percent of nonreturns from the Holstein bulls averaged 6.3 percent higher than that from the Guernsey bulls. The Guernsey bulls produced a greater average volume of semen. Partial correlations indicate both light and temperature may be positively correlated with spermatogenesis with light exerting the greater effect. Spermatogenic activity of both breeds reached a peak during the spring and was depressed during the fall and winter months. Peak Holstein fertility occurred in March and April. The percent of nonreturns for the Guernsey bulls was highest in October and November. Breeding results from both breeds were poorer in winter and summer then during the other seasons. Partial correlations indicate a negative effect of light upon fertility with greatest effect after a one month lag. Positive correlations between temperature and fertility of approximately the same magnitude as those for light were obtained.

WEANING WEIGHT OF CALVES AS RELATED TO AGE OF DAM, SEX AND COLOR. W. A. Sawyer, Ralph Bogart and Mohamed M. Oloufa, *Oregon Agricultural Experiment Station.*

Data on weaning weight of calves were analyzed by variance and covariance. The re-

gression of weight on age was 1.28 pounds per day. Between the ages of 25 and 35 weeks calves grew at practically a constant rate of 1.28 pounds per head daily. When the weight of all calves was adjusted to a weaning age of 30 weeks, it was possible to compare dams of different ages. Younger (2 year old) cows weaned calves 75 pounds lighter than mature cows. The weaning weight of calves increased with increasing age of dams through eight years but then declined. Heifer calves were heavier at weaning than steer calves but the difference lacked statistical significance. All animals were rated for color—yellow, light, medium, and dark red. Dark red calves were heavier at weaning and yellow cows weaned heavier calves but neither of these showed statistical significance. Yellow cows weaned heavier heifer and lighter steer calves than did dark red cows.

SIZE OF LAMBS AT WEANING AS A PERMANENT CHARACTERISTIC OF NAVAJO EWES. George M. Sidwell, *United States Department of Agriculture.*

The lifetime lamb production (1506 lambs) of 414 ewes was studied to estimate the degree to which size of lambs weaned is a permanent characteristic of Navajo ewes. The least squares method of fitting constants was used to analyze the data. Six measurable environmental factors had important effects on the weaning weights of the lambs. These were: (1) The year in which the lambs were born. (2) Age of dam. (3) Breed of sire. (4) Type of birth and rearing. (5) Sex. (6) Age of lambs at weaning. In culling ewes which lack the ability to produce heavy lambs, selection can be made considerably more accurate by adjusting lamb weights for these environmental factors. The intraclass correlation (repeatability) between the weaning weights of lambs raised by the same ewe was .217. This figure represents the fraction of the difference between two animals in one season that is most likely to be found in a later season. When ewes have produced more than one lamb, selection can be made more accurate by basing decisions on lifetime lamb production. The progress expected from selection based on an average of 2, 3, 4, 5, and 6 lambs is 1.22, 1.44, 1.55, 1.63, and 1.69 respectively, times greater than if selection is based on the record of one lamb only. These statistics are also useful in obtaining information about what to expect from selection and in planning future breeding programs which will have maximum effectiveness in promoting genetic improvement.

A STUDY OF HETEROSIS IN SWINE. Carl Frederick Sierk, *University of Minnesota.*

Performance data from 2213 pigs representing 373 spring farrowed gilt litters were studied. Included in this total were 42 litters and 322 pigs of the Minnesota No. 1 line; 52 litters and 348 pigs of the Minnesota No. 2 line; 141 litters and 797 pigs representing 9 different inbred Poland China lines; 67 litters and 350 pigs resulting from crosses of the inbred Poland China lines; and 71 litters and 396 pigs representing different cross combinations of the 3 breeds. The advantage or disadvantage of the crossbreds in comparison with the average of the parental stock was calculated for each of three measures of vigor, viz.: weaning weight, rate of gain, efficiency of feed utilization, in terms of percent. The average of these three measures was used as the over-all increase or decrease in vigor. Crosses of inbred lines within the Poland China breed resulted in an increase in vigor of 3.63 percent for each 10 percent decrease in Fx compared with 4.45 percent for No. 2-inbred Poland China crosses, 5.94 percent for No. 1-inbred Poland China crosses, and 11.30 percent for No. 1–No. 2 crosses. The best inbred line crosses showed approximately 15 percent advantage when compared with non-inbreds and non-inbred breed crosses. Inbred line crosses were less variable than the inbred lines in weaning weight, 154 day weight, and rate of gain.

A COMPARISON OF INBRED LINES OF SWINE BASED ON THEIR PERFORMANCE IN TOPCROSSES. H. A. Stewart and R. E. Comstock, *North Carolina State College.*

Four inbred lines of swine originating in the Regional Swine Breeding Laboratory are being appraised through the performance of their topcross offspring. Characteristics measured were post weaning rate of gain, carcass cutout value, and farrowing and suckling performance.

Two boars have represented each line each year. Each boar has been represented by two litters. Two of the inbred lines (a and b) are purebred Durocs, one (c) is purebred Poland China and the fourth (d) originated from genetic material not common to American breeds of swine. Females producing topcross litters were of Duroc, and Tamworth × Duroc breeding. Differences in the performance of topcross offspring by boars of lines a, b and c were small. Pigs by boars of line d were 10 pounds heavier at 154 days than those by boars of lines a, b, or c. Females by boars of line d averaged 1.55 more live pigs at birth, 1.6 more pigs at 56 days and 33 pounds greater total litter weight at 56 days than did females by boars from lines a, b, and c. Sixty-seven carcasses of topcross barrows were cut out and evaluated. The mean index of carcass value for the barrows by boars of line d was greater than that for the barrows sired by boars of lines a and b. These results are in agreement with the concept of the value of crosses between genetic materials of widely divergent origin.

ON THE DIFFERENTIATION OF FRATERNAL AND IDENTICAL TWINS IN CATTLE. Clyde Stormont and M. R. Irwin, *University of Wisconsin.*

Genes on seven or more chromosomes of cattle are known to affect 40-odd antigenic characters presently recognized in cattle erythrocytes. The average animal is usually heterozygous for three or more pairs of these genes so that even among full sibs identical blood-types are rare. On the other hand, it has been found that the majority of twin-pairs have identical blood-types, except for the J character. The identity of blood-types has been shown to be due to the presence of two distinct kinds of erythrocytes, one type presumably descendent from the individual's own hemopoietic tissues and the other from tissues that developed from embryonal cells which migrated from the co-twin during fetal life. Consequently, twins having identical blood-types could be of two kinds—(a) dizygotic twins having an admixture of each other's blood and (b) monozygotic twins. It is possible to distinguish like-sexed dizygotic twins with an admixture of bloods that differ in one or more antigenic components by visible quantitative reactions; the gross mixture of the two kinds of bloods is only partially hemolyzed by the respective reagents. Furthermore, in these a qualitative separation of one or both types of erythrocytes can be made. In contrast, all the cells of identical twins will react alike. Hence the technique of blood-typing should distinguish in most cases identical from non-identical twins.

THE HERITABILITY OF BODY SIZE OF HOLSTEIN-FRIESIAN AND AYRSHIRE CATTLE. W. J. Tyler, George Hyatt, A. B. Chapman and G. E. Dickerson, *West Virginia University and University of Wisconsin.*

The objectives of this study were to determine the heritability of body size (height at withers, circumference of shin bone, heart girth, width of hips) of Holstein-Friesian cattle at the age of six months (425 calves), 18 months (245 heifers), and at maturity (244 cows), and of body size (weight and height at withers) of Ayrshire cattle at six months (222 calves), 12 months (223 heifers), 18 months (211 heifers), and 36 months of age (202 cows). The intra-sire regression of daughter's measurements on dam's measurements and the paternal half-sib correlations were used to estimate the heritability figures. For the Holstein-Friesians, approximately 15 percent of the variation in body size at six months, 35 to 65 percent at 18 months, and between 30 and 60 percent at maturity were caused by hereditary differences between individuals. The heritability estimates for the Ayrshires were 20 to 35 percent at six months, 30 to 60 percent at 12 months, 20 to 40 percent at 18 months, and 15 to 30 percent at 36 months. These results suggest that selection for body size in dairy cattle could be effective in changing body size of subsequent generations.

SEX RATIOS AMONG INBRED, NONINBRED AND LINECROSS PIGS. E. H. Vernon, *Iowa State College.*

A study was made of 2887 litters consisting at birth of 10,924 males and 10,047 females.

The sex ratio declined with advancing age due to greater mortality among males than females. In the population studied the sex ratio was 52.1 percent males at birth, 50.1 percent at 21 days, 49.8 per cent at 56 days, and 49.5 percent at 154 days. Mortality up to 21 days was 30.3 percent among linecross males, 24.7 percent among linecross females, 41.5 percent among inbred males, and 38.2 percent among inbred females. These differences in mortality between sexes and between linecross and inbred pigs were highly significant. The inbred lines differed significantly in mortality and sex ratios. The sex × line interaction was large, particularly from birth to 21 days. Inbreeding, however, had no general effect upon the sex ratio. This was shown by similar sex ratios in the linecross and inbred populations, as well as by a regression analysis of sex ratios within litters on inbreeding of litters.

Extension Section

M. W. Muldrow, *Chairman*

LIVESTOCK PARASITE PROBLEMS. Benjamin Schwartz, *U. S. Department of Agriculture.*

Questions submitted to the speaker in advance of the meeting and, if time permits, those propounded at the meeting, on the control of livestock parasites will be answered. It is expected that the discussions will deal in the main with the control of internal parasites of swine by the judicious use of sodium fluoride as an ascaricide; the control of roundworms of cattle and sheep by treatment with phenothiazine; the control of sheep tapeworms by treatment with lead arsenate; the control of mange or scabies in hogs and sheep by treatment with benzene hexachloride; control of lice on domestic animals; and related livestock parasite problems.

Meats Section

K. F. Warner, *Chairman*

SHEAR TENDERNESS TESTS ON BEEF SHORT LOINS. L. H. Blakeslee and J. I. Miller, *Cornell University.*

There is a dearth of objective information on the tenderness of the several grades of beef. Therefore, data are presented in this paper on the shear tenderness of 10 beef short loins at 4 locations posterior to anterior. Two commercial, 2 good and 2 choice short loins were tested two days after slaughter. One good short loin was tested six days after slaughter. In like manner 3 choice short loins were tested, one at eight days, one at fourteen days, and one at twenty-four days after slaughter. Data are also presented on the shear tenderness of 18 paired short loins tested in a similar manner. Six of these paired short loins were graded choice, 6 good, 3 commercial and 3 utility. The method of sampling made it possible to test paired steaks after 2, 9, 16 and 23 days of aging. One of each pair was tested before freezing and the opposite steak after freezing at −10° F. and 3 or more months of frozen storage at 0°F. All shear tenderness tests were made after roasting in a 350° oven to a 136° F. internal temperature on the longissimus dorsi muscle only. A summary of the data shows that short loins are less tender at the rib end than at the porter house steak end. Analysis of variance of the 18 paired short loins tests shows a highly significant difference between 2 day aged beef and that aged longer, between grades, and between aged and aged and frozen samples.

THE ROLE OF SUGAR IN THE PRODUCTION OF SOUTHERN STYLE HAMS. T. N. Blumer, D. E. Brady, F. H. Smith and L. N. Tucker, *North Carolina Agricultural Experiment Station.*

In a study of hams cover-cured with from 0 to 43 percent sugar in the salt mix and aged 125 days at 65° to 70° F. at an average relative humidity of approximately 55 to 60 percent

it was found that the varying amounts of sugar had only a slight influence on the palatability and other important composition characteristics. The highest content of sugar found to be present in the tissues at the conclusion of curing was less than one percent. Equalization of the moisture and salt content was rather rapid during the first 26 days of aging. Acceptance studies indicate that hams produced in this manner and containing approximately 45 to 50 percent moisture and 5 to 6 percent salt meet with very favorable response.

ULTRAVIOLET IRRADIATION OF BEEF AND PORK FOR LOW TEMPERATURE STORAGE. D. E. Brady, F. H. Smith, L. N. Tucker and T. N. Blumer, *North Carolina Agricultural Experiment Station.*

The possible deleterious influence of ultraviolet irradiation in shortening the induction period with earlier onset of rancidity in the frozen product is the characteristic with which this paper is concerned. On the basis of the variables studied it was found that length of frozen storage period had the most pronounced effect in shortening the induction period and rancidity development. The effect of irradiation was least important and the length of holding period of intermediate influence. Little practical importance can be attached to peroxide values which while appreciable are of insufficient size to indicate rancidity levels which are organoleptically discernible.

MOLD CONTROL IN STORED CURED PORK. R. W. Bray and Flora Hanning, *University of Wisconsin.*

Trimming loss, off flavors and unattractiveness due to mold is a problem in the storage of cured meats. In three years, 1946 through 1948, several materials have been applied to the outside of hams, shoulders and bacons, in an effort to inhibit or retard mold growth and note their effect on the flavor of the meat. In these studies several proprietary materials have been used, one containing calcium propionate, another containing a special grade of oat flour, two proprietary waxes, linseed oil, lard alone, lard plus linseed oil, and lard plus a commercial antioxidant. Observations were made on the extent of mold growth, and palatability tests were made by the triangular or differential taste test. It was observed that the mold was inhibited with the materials containing calcium propionate and one of the proprietary waxes. A retardation in growth of molds was noted where the treatment consisted of linseed oil, one of the waxes and the special grade of oat flour. Weight losses during storage were least in the lard, lard plus linseed oil, and with the wax which inhibited the mold. The palatability committee found objection to flavor in the calcium propionate, lard, and lard plus linseed treated lots. The special grade of oat flour gave slight improvement in flavor over the control. Off flavors due to mold were observed in the control lot and lots where mold was not inhibited. Rancidity was noticeable in the lots where lard was applied. Further palatability tests are planned before detailed presentation is made.

A METHOD OF CURING PORK UNDER FARM CONDITIONS WITHOUT REFRIGERATION. J. B. Francioni Jr. and R. M. Crown, *Louisiana State University.*

After a series of carefully planned preliminary trials on procedures, experiments were designed to determine the months of the year pork could be slaughtered and cured under farm conditions without refrigeration. The experiments were performed during the twelve months from November, 1946 through October, 1947. One or more hogs were used each month. Every effort was made to conduct these experiments under conditions similar to those existing on farms in Louisiana. In all trials, pork was satisfactorily cured by the use of both the brine cure and dry cure methods. Under the same general procedure and conditions it was found that pork could be slaughtered and cured successfully from the middle of October to the middle of May where the atmospheric temperature did not register above 60° F. The meat to be cured was deboned and cut into several pieces weighing from 3 to 6 pounds. With atmospheric temperatures above 80° F, cracked ice had to be used to bring about rapid cooling of the warm

carcass and to aid in bringing and keeping the temperature at the center of the meat below 65° F.

A STUDY OF CERTAIN FACTORS OF QUALITY OF MEAT IN RELATION TO METHODS OF PROTECTION IN FREEZER STORAGE. R. L. Hiner, A. M. Gaddis and O. G. Hankins, *United States Department of Agriculture.*

Beef, pork and lamb cuts from animals produced and slaughtered by standard procedures were frozen and stored under conditions which controlled one or more of the important storage factors of desiccation, atmospheric oxidation, bacterial growth, and enzyme activity. Storage was for periods up to 83 weeks at temperatures of −11½°, 0°, 15°, and 18° F. Samples were stored without protection, wrapped in cellophane, dipped in gum-guaiac-treated lard, and vacuum packed. Meat stored at 0° F. was superior to that stored at higher temperatures for any given method of protection. However, vacuum packed samples stored at 15° and 18° F. were nearly equal to those stored at 0° and far superior to the samples having the other kinds of protection. Protection with gum-guaiac-treated lard was better than with cellophane with respect to desiccation as well as to oxidation and related factors. Chemical and organoleptic data indicate that the retention of fresh meat quality up to a year at temperatures from 0° to 18° F. was primarily a matter of preventing atmospheric oxidation of the fat. Apparently, in the absence of air, hydrolytic and oxidative enzyme activity was slight at temperatures as high as 18° F. Changes in the lean tissue such as slight proteolysis at above 0° F., increase in fluorescence, and large, progressive and variable decreases in soluble protein did not appear especially significant. Decrease in scores for flavor of lean, though moderate and rarely reaching the point of undesirability, seemed to reflect changes in desirability of flavor of fat.

THE EFFECT OF METHOD OF COOKING ON TENDERNESS OF BEEF AT DIFFERENT INTERVALS AFTER SLAUGHTER. Pauline Paul, L. J. Bratzler and E. D. Farwell, *Michigan State College.*

There has been considerable discussion as to whether or not beef cooked as soon as possible after slaughter would be tender. This experiment was designed to compare the effect of slow and rapid heat penetration on tenderness of beef cooked at different intervals after slaughter. The semitendinosus and biceps femoris muscles from three animals were utilized. Three steaks and three roasts were cut from each muscle. The six steaks and six roasts from each animal were paired, and the pairs distributed at random over the following time intervals after slaughter: 1–1½, 6, 13, 25, 49–54, and 145–150 hours. One steak and one roast from each muscle were cooked at each time interval. The steaks were fried in deep fat at 150° C. to an internal temperature of 63° C. The roasts were cooked in an oven at 163° C. to the same internal temperature as the steaks. The force required to shear the cores from the steaks increased up to the 13-hour interval, then decreased, while the force required to shear the cores from the roasts was highest at the 1–1½ hour interval and decreased thereafter. It is suggested that the cuts at the 1–1½ hour interval had not gone into rigor mortis, that the heat penetration through the steaks was sufficiently rapid to inactivate the enzymes present before rigor set in, but that heat penetration into the roasts was sufficiently gradual to induce heat rigor.

INITIAL PHYSICAL AND CHEMICAL CHANGES IN BEEF AS RELATED TO TENDERNESS. J. M. Ramsbottom and E. J. Strandine, *Swift & Company.*

Boneless loin steaks were cut from ten good and utility beef carcasses. They were tested at frequent intervals from two hours after slaughter until the twelfth day.

Representative steaks were frozen and later thawed for comparative tests. Data were collected on temperature, color, pH tenderness, palatability and histology of the meat.

Beef frozen at two hours after slaughter was lighter in color in the frozen state and darker in the thawed state than beef handled according to commercial practice. Beef which was chilled as boneless loins was less tender than beef which was chilled as carcass sides. The beef

was more tender at two hours following slaughter than it was at any time thereafter for the next two to six days. By the ninth and twelfth days after slaughter the beef had improved in tenderness so that it was more tender than it was at two hours following slaughter. A microscopic examination of the muscles showed that there was a significant relationship between the physical characteristics of the muscle fibers and the tenderness of the beef.

FACTORS INFLUENCING THE QUALITY OF FROZEN STORAGE MEAT. P. Thos. Ziegler and James A. Christian, *The Pennsylvania State College.*

The length of the prefreezing period affects the storage life of all types of meats and particularly pork. Meats chilled for 48 hours at 33 to 37° F. had longer storage life than aged meats. Sausage made from 24-hour chilled pork had several months' longer storage life than sausage made from pork that was aged 4 to 5 days. The tenderizing effect of aging on beef held 2 days, 4 days, 7 days, and 14 days was definitely in favor of the 14-day aging period for meat that was to be consumed fresh or as frozen beef during a 2-month period. This tenderization by aging was offset by the tenderization by freezing as the zero storage period progressed and was no longer a factor after 6 months of frozen storage. Beef frozen at −110° F. and stored at zero was more tender than beef frozen and stored at zero but had the same tenderness after 6 months of zero storage. Lamb and mutton had longer storage life than other meats. The type of wrapping material was important in maintaining quality in frozen meats after 6 months of storage. Aluminum foil .0015 gauge proved superior to other types and the waxed papers were definitely not adequate for storage periods over 6 months. A storage temperature of −20° F. gave a 3 to 6 months' longer storage life to meats. Zero storage of cured meats proved inadvisable. Liver and liver products stored well at zero but scrapple (without liver) had poor storage life.

Nutrition Section

T. J. Cunha, *Chairman*

THE EFFECT OF STOMACH WORM (*HAEMONCHUS CONTORTUS*) INFECTION ON SOME OF THE B-COMPLEX VITAMINS IN THE BLOOD AND RUMEN OF LAMBS. M. F. Badr, T. L. Bahler, A. L. Pope, C. A. Herrick, G. Bohstedt and P. H. Phillips, *University of Wisconsin.*

Previous experiments have indicated that lambs receiving certain minerals passed worm eggs earlier and had larger numbers of worms at autopsy following infection with the common stomach worm, (*Haemonchus Contortus*). At the same time, a higher protein level seemed to exert a protective effect. Further studies included 52 lambs born from ewes fed the following rations: Lot I, Basal (or low protein) and iodized salt; Lot II, Basal plus a mineral mixture consisting of $CuSO_4$, $CoSO_4$, $FeSO_4$, $MnSO_4$, and KI; Lot III, Basal plus protein; Lot IV, Basal plus minerals and protein. The lambs were creep fed the ewes' rations in their respective lots and were infected at approximately three months of age with varying doses of *Haemonchus Contortus* larvae. Some of the lambs in each lot were given follow-up doses of these parasites. Uninfected lambs in each lot served as controls. Studies included the synthesis of some of the B-complex vitamins in the rumen of fistulated lambs under this condition of parasitism. Blood analyses revealed a significant effect of infection on the B-complex vitamins. Data will be presented to show the effect of these parasites on growth, fecal egg count, post mortem worm count, hemoglobin, and plasma protein as well as their effect on vitamin B_6, thiamin, riboflavin, and nicotinic acid in the blood and rumen of these lambs.

TYPES AND NUMBERS OF MICROORGANISMS IN THE RUMEN CONTENTS OF CATTLE BEING FED NATURAL AND SEMI-SYNTHETIC RATIONS. A. L. Bortree, C. K. Smith, B. C. Ray Sarkar and C. F. Huffman, *Michigan State College.*

Estimates were made of the bacterial populations of the rumen contents of cattle on various types of rations. Rumen samples preserved with formaldehyde were stained with crystal

violet for making total counts and with Lugoll's solution for counting the iodine staining organisms. Four animals with rumen fistulas, two cows and two yearling bulls, were used in these studies. Samples were taken from three of these animals while they were being fed hay alone, hay and dextrose and pasture alone. The fourth animal received two pounds of hay per day and six pounds of the concentrate. The composition of the concentrate was changed at three week intervals and rumen samples were taken over a three day period for each change in the ration. When methionine was added to a ration made up of corn, starch, glucose, and minerals there was a marked difference in the physical condition of the rumen contents and a change in the type of iodine staining organism present. An iodine staining "giant spirillum" was present in large numbers when this ration was being fed. The addition of grain or a readily fermentable carbohydrate to a hay ration decreased the time required to reach the peak in the bacterial populations in the rumen.

EFFECT OF THE STAGE OF LACTATION AND RATION ON THE COMPOSITION OF SOW'S MILK. J. P. Bowland, R. H. Grummer, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

The composition of the colostrum and milk from twenty sows was studied. One group of sows was carried through gestation in dry-lot and a second group on pasture. The sows were milked manually after the injection of 1 ml. of Pitocin on the first day, third day, first week and each subsequent week during lactation. The mean values for the composition of colostrum from the dry-lot group were: total solids 24.54%, solids-not-fat 18.09%, fat 6.45%, protein 14.01%, total ash 0.73%, vitamin A 132.9 γ/100 ml., vitamin C 24.6 mg./100 ml.; for the pasture group were: total solids 22.90%, solids-not-fat 16.17%, fat 6.73%, protein 12.43%, total ash 0.76%, vitamin A 143.6 γ/100 ml., vitamin C 18.8 mg./100 ml. The mean values for the composition of normal milk from the dry-lot group were: total solids 20.79%, solids-not-fat 13.34%, fat 7.45%, protein 7.62%, total ash 0.97%, vitamin A 34.8 /γ100 ml., vitamin C 12.2 mg./100 ml.; for the pasture group were: total solids 19.50%, solids-not-fat 13.38%, fat 6.12%, protein 7.12%, total ash 1.00%, vitamin A 52.7 γ/100 ml., vitamin C 10.4 mg./100 ml. Lactational trends of all constituents were studied. The fat and vitamin A relationship was also determined.

THE EFFECTS OF THIOURACIL ON THE METABOLISM OF RATS. J. W. Bratzler, J. R. Barnes and R. W. Swift, *The Pennsylvania State College.*

Three diets, in which the level of thiouracil was the only variable, were compared in a 10-week growth, metabolism and body balance study using 24 male rats, selected as 8 sets of littermate triplicates, which were between 50 and 55 days of age when placed on experiment. Feed intake was controlled by the paired method. The rats receiving .1% thiouracil in their diet gained 1.7 times as much energy as those on the control diet, while the rats consuming the .2% thiouracil diet gained 2.2 times as much energy as the control animals. No significant differences were noted in the storage of energy as protein. The three groups metabolized essentially the same quantities of food energy but the thiouracil-fed groups produced less heat; 2536 Calories for the control group, 2471 Calories for the .1% thiouracil group, and 2405 Calories for the .2% thiouracil group. In addition to the determination of the total heat production by the body balance procedure, the hourly fasting heat production was determined by the Haldane procedure between the 4th and 6th weeks of the experiment. The average hourly fasting heat productions were 758, 673, and 634 calories for the control, .1% thiouracil and .2% thiouracil groups, respectively.

EFFECT OF HOG WALLOWS ON GAINS OF FATTENING SWINE. Chas. I. Bray and C. B. Singletary, *Louisiana State Experiment Station.*

Three lots of 8 pigs each averaging 79 pounds, mixed sows and barrows, were fed out on small pastures for a period of 73 days. Lot 1 had no wallow, Lot 2 a portable wallow, and Lot 3 a mud wallow. The average gains in 73 days were as follows: Lot 1, no wallow—1.456 lbs.

per day; Lot 2, sanitary wallow—1.805 lbs.; and Lot 3, mud wallow—1.850 lbs. per day. The difference in gains between Lots 2 and 3 was not significant, but the difference was quite marked between the pigs having wallows and those with none. The best gaining pig in Lot 1 (dry lot) made the same gain as the poorest gainer in Lot 2 (sanitary wallow). The pigs with wallows ate more feed, leaving their shelters at intervals during the day, cooling off in the wallows and then going to the self-feeders. Those with no wallow rarely came out between eight in the morning and five in the afternoon. Body temperatures on hot days for pigs without wallows sometimes reached temperatures of 105° to 106°. Hogs just out of the wallow had temperatures as low as 102°, while the average temperature of those in the lots with wallows ran around 104°. The maximum temperature in the sheds ran to 104° and 105° on hot days. The feed consumption per 100 lbs. gain to August 7 was: Lot 1—386 lbs.; Lot 2—351 lbs.; and Lot 3—355 lbs. per 100 lbs. gain. One barrow in the mud wallow broke out with a skin eruption the last day of the test, but it is not certain whether this was due to the wallow.

INFLUENCE OF ALFALFA ASH AND WATER EXTRACT OF ALFALFA UPON ROUGHAGE DIGESTION IN CATTLE. Wise Burroughs, Paul Gerlaugh and R. M. Bethke, *Ohio Agricultural Experiment Station.*

In earlier digestion trials, the addition of corn starch to steer rations resulted in severe decreases in digestibility of certain roughages with little or no reduction in digestibility of certain other roughages. Good quality alfalfa hay was influenced least by starch additions while corn-cobs were affected most with timothy hay and stemy clover hay occupying intermediate positions. The addition of casein to low protein roughages in these earlier trials was effective in partially preventing the depressing action of starch but the additional protein was not completely protective. Alfalfa hay was fractionated by ashing and by extracting with warm water for purposes of determining whether alfalfa contained properties other than protein beneficial to the utilization of a poor quality roughage. Alfalfa ash and alfalfa water extract were added separately to a basal ration containing corn-cobs, starch, dried skimmilk, bone meal, salt, and vitamin A and D feeding oil. Both additions resulted in improved utilization of corn-cobs based upon dry matter and organic matter digestibility. The apparent coefficient of digestion of corn-cob organic matter averaged about 35 percent with the basal ration and about 50 percent when either of the additions was made to the basal ration. Repeat experiments using similar feeds and feed fractions over extended collection periods produced similar results.

STUDIES ON YOUNG PIG MORTALITY. Damon Catron, C. C. Culbertson and P. S. Shearer, *Iowa State College.*

The nutritional adequacy of a plant protein basal ration was investigated in three swine and two rat experiments conducted concurrently. The gestation-lactation performance was not improved significantly by addition of 10 percent high-quality dehydrated alfalfa meal as a source of water-soluble vitamins. Addition of animal protein to the basal ration fed to sows during gestation and/or lactation failed to increase pig livability and growth significantly. Feeding supplemental alfalfa extract with the basal ration to female rats during pregnancy and/or lactation improved neither the livability nor growth rate of the young. Statistical analysis of data on blood hemoglobin of pigs failed to reveal any significant differences that might be attributed to the ration fed during gestation or lactation. Chemical analysis of carcasses of pigs from sows fed different rations did not show consistent differences. Nicotinic acid, pantothenic acid and riboflavin content of sows' milk was influenced by the ration fed during either gestation or lactation. Riboflavin content of sows' milk was increased significantly by supplementing the ration with alfalfa meal as a source of this vitamin. No definite relationship, however, could be established between the vitamin content of the sows' milk and livability or growth of pigs. Determination of the gamma globulin content of blood from sows and litters did not reveal definite differences attributable to treatment. The higher degree livability and growth obtained by feeding plant protein during gestation and lactation stages does not corroborate previous investigations.

SOME EFFECTS OF COBALT IN THE SHEEP RATION. Charles C. Chamberlain, G. A. Branaman, L. H. Blakeslee, R. H. Nelson and F. Thorp, *Michigan State College.*

Six pairs of lambs were used in a paired feeding experiment to determine the effects of supplemental cobalt where there were no pronounced symptoms of the deficiency. A forty-five percent corn and fifty-five percent hay ration was used with one milligram of elemental cobalt in solution per lamb added daily. There was no difference in the rate of gain for the first ten weeks of the experiment. In the last four weeks the cobalt group out-gained the controls by nine and one-half pounds. During the fourteen weeks the cobalt lambs required only ninety percent as much feed. Bacteriological studies of the rumen contents showed only small differences and the significance was not clear. Liver analyses showed about three times as great a cobalt concentration in the cobalt as in the control lambs. Additional studies on the effect of supplemental cobalt in the ration of pregnant ewes were made. At a one-hundred milligram daily per ewe level, it was possible to increase the cobalt content of the milk four to fifteen times. Twelve days after placing the ewe and lambs on pasture, and discontinuing cobalt, the cobalt level of the milk was the same for both groups, and below the previous level of the controls. There was little difference in the growth rate between the two groups of lambs. There was an appreciable difference in hemoglobin values of the lambs. The control group showed declines of sixteen to thirty-seven percent over a two to four week period and required two to three additional weeks to recover. There was a gradual lessening of this drop as the ewes received cobalt before lambing. When cobalt was fed for thirty days prior to lambing there were cases where there was no drop in hemoglobin values of the lambs. It seems possible that there might have been some placental transfer of cobalt affecting the hematopoietic centers preventing this early anemia.

ALFALFA AND SOIL AS A SOURCE OF AN UNIDENTIFIED FACTOR(S) AND THE VALUE OF OTHER VITAMINS FOR THE YOUNG PIG. T. J. Cunha, R. W. Colby, H. W. Hodgskiss, T. C. Huang and M. E. Ensminger, *State College of Washington.*

With a purified ration, alfalfa and soil were shown to supply an unknown factor(s) which stimulated appetite for the pig thereby increasing rate of gain. Pigs fed 5 percent soil had higher hemoglobin values than pigs fed the basal ration alone or plus 10 percent alfalfa. Soil fed at a 5 percent level for too long a period is perhaps deleterious to the pig. Pigs fed a purified ration deficient in all B-complex vitamins did not develop any outward deficiency symptoms. They just failed to grow and looked like runts. On autopsy the pigs showed very little gross pathology. Addition of soil to a ration deficient in all B-complex vitamins was of no benefit. With rations containing 14 to 15.1 percent protein, folic acid supplementation increased the rate of gain and in two out of three trials was of benefit in increasing efficiency of feed utilization. With rations containing 16.4 to 18.4 percent protein, folic acid supplementation was of no benefit in increasing rate of gain. It seems that folic acid needs are related to protein level. With lower protein content rations, folic acid stimulates appetite causing the pigs to consume more feed. With a methionine low ration, biotin was of benefit in promoting efficiency of feed utilization, thus indicating a possible interrelationship between these two factors. Ergostanyl acetate, a guinea pig "antistiffness factor," was of no benefit in curing or alleviating a stiffness which is characteristic of pigs kept on concrete floors.

THE EFFECTS OF STILBESTROL, TESTOSTERONE AND THYROID ALTERATIONS ON GROWTH AND FATTENING OF BEEF HEIFERS. W. E. Dinusson, F. N. Andrews and W. M. Beeson, *Purdue Agricultural Experiment Station.*

Results of two years research on the effect of experimental alteration of the sex glands and the thyroid indicate that these glands play an important part in the growth and fattening of beef heifers. In both experiments Hereford heifer calves weighing about 500 pounds were full-fed alike. In the first experiment five lots of five heifers each were fed for 140 days. The treatments consisted of: (1) control, (2) spayed, (3) stilbestrol (42 mgm. pellet subcutaneously), (4) testosterone propionate (50 mgm. intramuscular injection followed by 32.5 mgm. injection

56 days later) and (5) thiouracil (4 gm. per head daily mixed with the soybean oil meal). The average daily gains were 2.07, 1.91, 2.32, 2.10 and 2.13 pounds respectively. These differences approached significance. In the second experiment the treatments were the same with the exception that the testosterone was administered as a 50 mgm. pellet subcutaneously and, the thiouracil discontinued and replaced by thyroprotein (½ gm. per hundred pounds body weight daily mixed in soybean oil meal). Three lots of three animals each were placed on each treatment. The average daily gains for 185 days were: control, 1.72; spayed, 1.54, stilbestrol, 2.00; testosterone, 1.73; and thyroprotein, 1.59 pounds. Stilbestrol treated heifers consumed significantly more feed and required significantly less feed per pound of gain. Frequent estrus periods did not depress gains. Analysis of the blood constituents, cholesterol and calcium, show no significant differences. The blood inorganic phosphorus decreased at a significantly less rapid rate in thyroprotein and stilbestrol treatments. The erythrocyte count was significantly lower in the stilbestrol treated group.

KNOWN AND UNIDENTIFIED FACTORS SUPPLEMENT A CORN-SOYBEAN MEAL RATION FOR WEANLING PIGS. I. A. Dyer, J. L. Krider and W. E. Carroll, *University of Illinois.*

Weanling pigs were group-fed in drylot to weights of 75, 100, 75 and 75 pounds in test A, B, C and D, respectively. In test A, the basal ration contained 20% crude protein and consisted of 63.5% ground yellow corn, 34% expeller soybean meal, 0.5% fortified A and D oil, and 2% complex mineral mixture. The basal ration for test B was same as for test A+5 B-vitamins (B_1, B_2, B_6, niacin and pantothenic acid). In tests C and D part of the corn and soybean meal was replaced by the supplemental feeds being assayed and choline was added to these basal rations. The supplements fed, per 100 pounds of ration, and average daily gains in pounds were as follows: Test A (1) basal (0.38); (2) basal+150 mg riboflavin (0.71*); (3) same as (2)+500 mg. niacin (0.72*); (4) same as (3)+600 mg. pantothenic acid (0.95**); (5) same as (4)+600 mg. thiamin+250 mg. pyridoxine+25 g. choline chloride (0.95**); and, (6) basal+25 g choline chloride (0.83**). Test B (1) basal (1.03); (2) basal+0.2% dl-methionine (1.19**); (3) basal+25 g. choline chloride (1.15**); (4) basal+0.2% dl-methionine+25 g choline chloride (1.19**). Test C (1) basal (0.98); (2) basal+5% meat scraps (1.05); (3) basal+2% fortified dried whey by-product (1.05); (4) same as (3)+5% meat scraps (1.17**); (5) basal +2% condensed menhaden fish solubles (1.10**); (6) basal+4% penicillium meal (1.00). Test D (1) basal (0.98); (2) basal+5% meat scraps (1.05); (3) basal+8% dried skim milk (1.14**); (4) basal+2.5% meat scraps+4% dried skim milk (1.12*); and (5) basal+2% condensed fish solubles (1.10**). The statistical significance is given for each supplemented lot over the basal lot in the same test (*$P \leqq 0.05$; **$P \leqq 0.01$).

THE EFFECT OF CRUDE SOYBEAN LECITHIN ON THE ABSORPTION AND UTILIZATION OF VITAMIN A FED PREPARTUM TO THE EWE AND SOW. H. D. Eaton, J. A. Christian, F. C. Daugherty, A. A. Spielman and L. D. Matterson, *University of Connecticut.*

Three groups each of pregnant ewes and pregnant sows were fed as follows: I basal ration, II a basal ration plus 200,000 I.U. of vitamin A daily, and III a basal ration plus 200,000 I.U. of vitamin A and 4 grams of crude soybean lecithin daily. Vitamin A alone or with the addition of soybean lecithin was fed prepartum for an average of 15 days to the ewes and 30 days to the sows. Blood samples were drawn at the start of the experiment, at parturition, and 30 days postpartum from 50 ewes and 14 sows, from 8 newborn lambs and 14 newborn pigs, from 62 30-day old lambs and 89 30-day old pigs. In addition whole livers were removed from 14 and 24 newborn and 12 and 18 30-day old lambs and pigs respectively. Both blood plasma and livers were analyzed for carotenoids and vitamin A. Maternal blood plasma vitamin A levels were higher in groups II and III; however, these differences were not statistically significant. The addition of soybean lecithin had no significant effect in elevating maternal blood plasma vitamin A levels. The level of vitamin A in newborn blood plasma was higher in lambs

and pigs from dams in groups II and III. These differences were not statistically significant. Both lambs and pigs at 30 days of age from dams in groups II and III were significantly higher in blood plasma vitamin A levels than those animals from dams in group I. Total liver storage of vitamin A and concentration per gram of liver at birth and at 30 days of age was significantly higher in those lambs and pigs from dams in groups II and III. The addition of soybean lecithin did not result in significant increases in the vitamin A levels found in the blood plasma and livers of newborn and 30-day old lambs and pigs.

POTASSIUM VS. BIOTIN IN THE TREATMENT OF EXPERIMENTALLY INDUCED PARALYSIS IN CALVES. R. J. Flipse, C. F. Huffman, C. W. Duncan and F. Thorp, Jr., *Michigan State College and Michigan Agric. Expt. Station.*

Twenty calves were placed on synthetic milk rations which varied only in the carbohydrate source and in the potassium content of the mineral supplement. All five of the calves which received cerelose as the carbohydrate and no potassium supplement developed paralysis in from 5 to 63 days after being placed on the experiment. None of the calves which received starch, dextrin, or a potassium supplement developed paralysis. The paralysis was of a progressive nature, involving in order the rear legs, fore legs, neck and respiratory system. If untreated, death resulted in from 12 to 24 hours after the appearance of initial symptoms. Cures were effected in four of the five calves (the fifth was killed in the late stage of paralysis and autopsied) by the oral administration of a potassium salt or the subcutaneous injection of biotin. Improvement frequently was noted within 3 hours after treatment, and recovery usually was complete within 30 hours.

THE EFFECT OF A RATION LIMITED TO PASTURE DURING THE DRY-REST PERIOD ON THE VITAMIN A AND CAROTENOID CONTENT OF THE BLOOD OF THE NEWBORN CALF. F. C. Fountain, D. B. Parrish, F. W. Atkeson and J. S. Hughes, *Kansas State College.*

Previous investigations have shown that the vitamin A reserves in the blood of the newborn calf are lower when carotene is the source of vitamin A than when vitamin A *per se* is fed to the dry cow. In the present study 9 cows, 4 Holsteins, 3 Jerseys, and 2 Ayrshires, received a ration limited to pasture from the beginning of the dry period until approximately 3 days prepartum, at which time they were brought to the barn and fed alfalfa hay and sorgo silage. No grain was fed at any time during the dry period. At birth and before colostrum ingestion, the average vitamin A content of the blood of calves born of these cows was 8.60 micrograms per 100 ml. This is significantly higher ($P<.01$) than the average of 3.69 previously obtained at this station on 41 calves whose dams were fed the usual dry-cow ration of hay, silage and grain, and also significantly higher ($P<.01$) than the average of 4.69 micrograms in the blood of 19 calves whose dams received pasture, hay and grain during the dry period. The average value obtained in the present study does not vary significantly from that of 7.91 micrograms per 100 ml. found in the blood of 37 calves whose dams had received supplements of either vitamin A ester or vitamin A alcohol during the dry period. The average carotenoid content of the blood of the newborn calves was 3.51 micrograms per 100 ml., which is not significantly different from previous values found at this station.

RUMEN BACTERIA IN CATTLE AND SHEEP ON WINTER AND SUMMER RATIONS. L. S. Gall, Wise Burroughs, Paul Gerlaugh and B. H. Edgington, *Ohio Agricultural Experiment Station.*

This study was undertaken to obtain information concerning the kinds and numbers of bacteria found in the rumen of cattle and sheep on practical farm rations. Cattle and sheep on fattening and breeding rations and pasture, as well as cattle on dairy rations with and without ensilage, were sampled. Samples were obtained by stomach tube and the solid material collected for study. The technics used were direct slide counts, Gram stains and anaerobic cul-

tural methods. Bacteria counts on both cattle and sheep on all winter rations showed about 150 billion bacteria/gm. of fresh rumen contents. On pasture, cattle averaged 96.1 billion and sheep 85.4 billion. Gram stains from both cattle and sheep on winter rations were very similar with the exception that animals fed high grain showed more cocci. The Gram stains from animals on pasture resembled those from animals on winter rations, but a few organisms seldom or never seen on winter diets appeared, such as sarcina and a star-shaped organism. Cultural results from both species were about the same, growth usually occurring in the one billion to 10 billion dilution, but the high grain animals showed more fast-growing organisms and higher growth than the low grain or pasture animals. Using these technics the kinds and numbers of bacteria in both cattle and sheep on winter rations do not appear markedly different. In stains, animals fed pasture show similar bacteria, but have a higher slide count and a few different bacteria than the same animals on winter rations.

RUMEN BACTERIA IN COBALT DEFICIENT SHEEP. L. S. Gall, S. E. Smith, D.E Becker, C. N. Stark and J. K. Loosli, *Ohio Agricultural Experiment Station and Cornell University.*

Twenty-one lambs became cobalt deficient after 6 months on a ration low in cobalt* after which they were divided into three equal groups. One group served as controls, a second was fed cobalt, while a third received cobalt by injection. Four sheep on pasture were used as normal controls. Several sheep were maintained for a month on restricted food intake comparable to the cobalt deficient animals, but with added cobalt. One week after treatment when the cobalt fed lambs showed signs of recovery, 2/3 of the sheep from each group were sampled by stomach tube. The solid material was collected and tested for the kinds and numbers of bacteria in the rumen contents by means of direct slide counts, Gram stains and anaerobic cultural methods. The remainder of the sheep were tested 2 weeks after treatment was started. Differences in the bacterial flora of cobalt deficient and cobalt fed sheep were detected by these three tests. The slide counts for cobalt fed sheep showed 54.6 billion per gram of fresh material, while the cobalt deficient animals averaged only 30.2 and cobalt injected sheep 30.7 billion. By observing the Gram stain, it was possible to separate all the cobalt fed sheep from the control lambs, while 5 out of 7 of the cobalt injected animals resembled the controls. Culturally the cobalt fed lambs showed more fast growing organisms and higher total growth than the cobalt deficient animals. Culturally the cobalt injected animals fell between these groups. Results from the sheep on restricted diet are incomplete at present.

THE VALUE OF SWEET BLUE LUPINE SEED AS A PROTEIN SUPPLEMENT FOR GROWING AND FATTENING BEEF STEERS. R. S. Glasscock and J. A. Hamilton, Jr., *Florida Agricultural Experiment Station.*

Four pairs of steers were selected so members of each pair were as nearly alike as possible with respect to age, weight, breeding, type, quality and grade. All steers received prairie hay as a roughage and a carbohydrate concentrate consisting of corn and oats. One member of each pair received cottonseed meal as a protein supplement while its pair mate received an equal amount (by weight) of ground sweet blue lupine seed. The protein supplements were mixed with the carbohydrate concentrates in the ratio of one part to four. The rations were controlled so each steer within a pair consumed the same quantity of feed. Average individual initial weight was 436 pounds for the steers assigned to the cottonseed meal as compared with 438 pounds for their pair mates. After 130 days on feed the average weight was 763 pounds for steers that had been fed cottonseed meal as compared with 778 pounds. The average daily gains were 2.52 and 2.62 pounds respectively. Feed consumed for 100 pounds gain averaged 935 pounds for the cottonseed meal group and 927 for the other group. Shrinkage in transit to market averaged 6.89 percent for steers fed cottonseed meal as compared with 8.18 percent. Average weight for carcasses was 404 pounds for the control group and 408 pounds for steers fed lupine. All carcasses in both groups graded U. S. Good. Statistical analysis of data failed

to show significant differences in results produced by the rations with respect to weight gains, dressing percentages, or feed consumed per unit of gain.

THE EFFECT OF MANGANESE SUPPLEMENTATION ON THE GROWTH OF SWINE FED RATIONS HIGH IN CORN AND CORN BY-PRODUCTS. Robert H. Grummer, Orville G. Bentley, P. H. Phillips and Gustav Bohstedt, *University of Wisconsin.*

Four lots of pigs were fed a basal ration composed of corn, soybean oil meal, corn gluten meal, ground alfalfa, salt, and limestone. The basal ration, containing 12–13 ppm. manganese, was supplemented with manganese at 3 levels, 40, 80, and 160 ppm. In each of 4 trials pigs receiving 40 ppm. manganese made the most rapid gain and the ration consumed per pound gain was less. The lots receiving 80 ppm. manganese grew more than the basal lots but less than the pigs receiving 40 ppm. Pigs given manganese at the 160 ppm. level did no better than the basal group. No significant differences were observed in dressing percentages, bone ash, or in the level of vitamin C or A in blood. Additional manganese tended to improve fertility but did not affect the lactating ability of sows selected from the 4 groups. Analysis of liver, kidney, pancreas, ovaries, and blood for manganese failed to demonstrate a correlation between manganese intake and the tissue concentration.

THE EFFECT OF FEEDING THYROPROTEIN AND THIOURACIL IN FATTENING RATIONS FOR DUROC SWINE. Fred Hale, George L. Robertson, Carl M. Lyman and William A. Wyatt, *Agricultural and Mechanical College of Texas.*

After a twenty-eight day preliminary feeding period, twelve barrows and twelve gilts were selected as test animals on the basis of uniformity and thriftiness. These animals were then placed in individual feeding pens where they remained until the end of the test. During a second twenty-eight day period half the animals of each sex were fed a basal ration with .01 percent thyroprotein added, while the remaining half were fed the basal ration only. During the third period of 35 days some animals of each sex which had been exposed to different previous treatments were fed either the basal ration, .15 percent thiouracil, or .25 percent thiouracil. Those hogs receiving .15 percent thiouracil showed the most economical gains with those previously fed thyroprotein being somewhat more efficient producers. The rate of gain was not quite so rapid for either group fed thiouracil as for the group fed basal ration throughout the entire test. Thyroid weights were greater in all swine fed thiouracil than in those fed only the basal ration. Animals which were fed thyroprotein prior to thiouracil produced smaller thyroids than those which received basal ration prior to thiouracil. White blood cell count was consistently lower in those animals receiving thiouracil. Liver weights increased as the level of thiouracil increased. A second test is in progress at the present time and results will be ready for presentation in November.

THE EFFECT OF VITAMIN C ADMINISTRATION UPON BLOOD PLASMA VITAMIN C LEVELS IN YOUNG LAMBS. W. H. Hale, A. L. Pope, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Previous work has shown that the plasma vitamin C level of lambs the first four days of life is markedly below that of their dams. This work was designed to correlate this low vitamin level with growth and mortality of infant lambs. Twenty-one sets of twins were bled at birth and one of the twins was given 200 mg. of vitamin C orally immediately following the bleeding. The plasma vitamin C level of these 42 lambs was determined at regular intervals until the lambs were 28 days of age. Plasma levels of this vitamin at birth for the untreated lambs was .34 mg./100 ml., and for the treated group .29 mg./100 ml. The levels for the untreated lambs decreased until the 7th day, when an increase occurred. The level of the treated lambs increased approximately twofold by the first day due to the vitamin C administration and remained higher than the level of the untreated group until the 5th day. On the 7th day a

second rise was observed that corresponded to the rise in the untreated group at approximately the same time. Single lambs of various ages were bled every 2 hours after vitamin C administration to determine the rate of increase in the blood plasma. There was no significant difference in growth rate between the treated and untreated groups. In order to have the largest possible number of lambs for the mortality phase of this experiment over 1000 capsules were distributed to flock owners out in the field, involving approximately 2000 lambs. The University flock was also used, and where alternate lambs received 200 mg. of vitamin C at birth in both cases. Preliminary observations indicate slightly fewer death losses up to one week of age in the group receiving vitamin C therapy.

THE FERTILITY OF BOARS FED A VITAMIN E DEFICIENT RATION. L. E. Hanson and I. L. Hathaway, *Nebraska Agricultural Experiment Station.*

Nine boars were fed in three groups of three. Group 1 was fed a natural diet previously shown to be adequate for fertility. Group 2 was fed a purified diet of crude casein, corn starch, lard, Brewers' yeast and salt mixture, plus a vitamin A and D concentrate. Group 3 was fed the same diet as group 2 and in addition each boar was given an average weekly supplement of approximately 340 mg. alpha tocopherol by mouth. The boars were placed on the test ration, November 15, 1947, at an age of 47 to 56 days and at weights ranging from 17 to 39 pounds. The boars in groups 2 and 3 were produced by sows similarly fed during part of the growth period and all of the gestation-lactation period. One of the boars in group 1 was a littermate of boars in groups 2 and 3, the others were from two sows raised in confinement on a natural ration. Rat assays of the purified diet were made at regular intervals. Sixty-one matings were made with gilts from the Station herd in April, May and June 1948. The results of these matings will be reported.

REPRODUCTION AND LACTATION STUDIES OF SWINE FED CORN-SOYBEAN OIL MEAL RATIONS. A. A. Heidebrecht, O. B. Ross, R. W. MacVicar and C. K. Whitehair, *Oklahoma A. & M. College.*

Twenty gilts were placed in dry lot and fed a basal ration composed of ground yellow corn, soybean oil meal, 5 percent alfalfa leaf meal, salt, and ground limestone for 105 days prior to breeding. The rations fed each lot during gestation and lactation, the percentage of pigs weaned of those alive at birth, and the average weaning weight per pig were respectively: (1) basal ration, 16.7 percent, 19.8 pounds; (2) basal ration+alfalfa silage (ad lib), 66.7 percent, 26.6 pounds; (3) basal+4 pounds of buttermilk per sow per day, 27.3 percent, 21.5 pounds; (4) basal+3 percent liver and lung meal, none weaned; (5) basal ration+ injectable liver extract approximately two months prior to farrowing, 38.9 percent, 24.0 pounds; (6) basal+ green rye forage 14 days before farrowing, 16.7 percent, 7.5 pounds. Colostrum samples were taken at time of farrowing for analysis of the vitamins shown below. Milk samples were obtained by intravenous injection of the oxytocic principle of the pituitary (pitocin, Parke-Davis and Co.) on the 5th, 15th and 55th day of lactation. These milk samples were analyzed for solids, fat, protein, ash, carotene, vitamin A, ascorbic acid, riboflavin, thiamin, pantothenic acid, and nicotinic acid. Milk, (fortified with iron, copper and manganese) from the sows in each lot was fed to weanling rats. Weekly growth rates among the lots ranged from 28.5 to 33.4 grams.

NEW FACTOR(S) PRESENT IN ANTIPERNICIOUS ANEMIA LIVER EXTRACT STIMULATES GROWTH IN BABY PIGS. B. Connor Johnson and A. L. Neumann *University of Illinois.*

Twenty-four to forty-eight-hour old pigs showed a marked growth response to antipernicious anemia liver extract preparations when they were added to a "synthetic" type ration containing "alpha-protein" (from soy bean) plus methionine as the protein source. This response does not appear to be due to any vitamin previously established as required by the pig

but is presumably identical with the "animal protein factor." The effect of this growth factor was not as marked when it was added to a casein synthetic milk ration but was still apparent. Some quantitative data on the requirements of the baby pig for this factor will also be reported.

THE EFFECT OF AMOUNT AND KIND OF PROTEIN FED UPON THE BLOOD SERUM PROTEINS OF PREGNANT EWES AND THEIR LAMBS. Earle W. Klosterman, M. L. Buchanan and D. W. Bolin, *North Dakota Agricultural College.*

Four lots of 10 ewes each were fed a basal ration of grass hay, yellow corn and minerals. Three levels of dried milk and one of linseed meal were added to make up the rations for the four lots. All ewes were bled at two week intervals with a total of 560 samples analyzed. Statistical analysis of the data from the three lots fed dried milk showed a significant increase in oxyhemoglobin with decreased amounts of protein fed. Ewes fed linseed meal had significantly lower oxyhemoglobin levels than those fed dried milk. There was a decrease in serum total proteins with decreased amounts of protein fed, a difference due entirely to a decrease in albumins. Source of protein fed had no effect upon serum protein levels. Analysis of the data as to number of lambs produced showed the ewes not lambing to have higher oxyhemoglobin levels than those that did lamb. There was a highly significant decrease in total proteins as the number of lambs produced increased, a difference due to a very marked decrease in globulins which was partially offset by a significant increase in albumins. No differences were found between the oxyhemoglobin or albumin levels of the lambs produced by the ewes from the four lots, but there was a highly significant decrease in both at 24 hours as compared with birth. Serum globulins were extremely low at birth but were greatly increased by one day of age. One ewe that became sick during the experiment showed a marked increase in serum globulins, a condition which has also been noted in a number of dairy cows that developed infections.

PANTOTHENIC ACID DEFICIENCY IN SWINE ON DIETS OF NATURAL FEEDSTUFFS. W. N. McMillen, R. W. Luecke and F. Thorp, Jr., *Michigan State College.*

Pasture raised pigs with an average initial weight of 23 pounds began goose stepping in seven weeks when fed a ration of corn 87, soybean oil meal 5.5, casein 5.5, complex mineral 2 plus liberal amounts of A and D supplements, thiamine, riboflavin, niacin and pyridoxine. Control pigs getting 25 milligrams of pantothenic acid per pound of feed in addition remained normal, made an average daily gain of .77 pound compared to .68 pound for the deficient pigs and significantly higher gains after the seven weeks period. Dry lot raised pigs started at 24 pounds showed severe goose stepping in seven weeks on a ration of corn 87, casein 10, mineral 3 plus the above listed vitamins except pantothenic acid. The control pigs receiving pantothenic acid averaged 1 pound daily gain to .77 pound for the deficient pigs. The blood pantothenic acid level was 1.64 ug/ml. for the controls and 0.89 for the experimental pigs. Urinary excretion of pantothenic acid was very low in all the deficient pigs. The influence of the pantothenic acid deficiency on urinary excretion of the B vitamins, economy of gain and nerve pathology will be discussed.

SUPPLEMENTARY FEEDING OF INDIVIDUAL SHEEP ON THE WINTER RANGE. Lloyd E. Meldrum, Lee A. Sharp, Lorin E. Harris, C. Wayne Cook, Laurence A. Stoddart and Louis L. Madsen, *Utah Agricultural Experiment Station.*

Thirty-six control ewes were herded with 108 individually fed ewes. The performance of these sheep was compared with 36 controls kept in a large range herd on the same area. Eighteen ewes, in each of six treatments, were fed individually in portable pens every other day: barley 0.4 lb. and 0.76 lb.; soybean oil meal pellets 0.28 lb. and 0.56 lb.; and monosodium phosphate 0.46 oz. and 0.60 oz., respectively. The high level of barley, the low and high levels

of soybean oil meal pellets, and the low level of monosodium phosphate produced greater gain than either of the control groups. The high level of soybean oil meal pellets increased fleece weights over those of the control ewes. All supplemental-fed ewes had a higher lamb crop than the controls with the exception of those fed the high level of barley. Since the small herd controls were slightly better than the large herd controls in live weight gains, fleece weight and lamb crop it can be assumed that under the conditions of this experiment the individual feeding, weighing and method of herding were not detrimental to the animals or the results obtained. This technic opens the way for the solution of problems involved in feeding various supplements to sheep on the range, since it overcomes the difficulty of fencing pastures and assessing differences among pastures.

THE AMINO ACID REQUIREMENTS OF SWINE; II. LYSINE. E. T. Mertz, D. C. Shelton and W. M. Beeson, *Purdue Agricultural Experiment Station.*

To determine whether lysine is an indispensable amino acid for growing pigs, eight pure-bred Duroc pigs averaging 35 pounds were litter paired and divided into two groups. Four animals were placed on a ration composed of zein 26.1 percent, dextrose 27.5 percent, dextrin 25.0 percent, lard 11.0 percent, mineral 55.2 percent, celluflour 2.0 percent, liver extract 0.5 percent, DL-tryptophan 0.4 percent, glycine 0.13 percent, L-histidine HCl 0.17 percent and DL-lysine HCl 2.0 percent. The remaining four animals were fed the same diet, except the 2.0 percent DL-lysine HCl was replaced with 2.0 percent dextrose. The animals receiving lysine made a daily gain of 0.91 pound per day and consumed 3.72 pounds of feed per day for 42 days. The animals on the lysine-deficient ration for 28 days showed neither a gain or loss in weight. The feed consumption of the lysine-deficient pigs for the first 14 days was 2.81 (controls, 3.14) pounds per day and for the second 14 days was 1.42 (controls, 3.63) pounds per day. In addition, the deficient pigs showed a depraved appetite, rough hair coat and symptoms of inanition. After the deficient period, the animals were changed to the diet which contained 2.0 percent DL-lysine HCl. The depraved appetite disappeared, the pigs became more thrifty in appearance and the appetite increased. By the end of one week all of the animals showed significant increases in weight. The animals were continued on the lysine diet for 28 days. During this period, they showed an average daily gain of 0.77 pound as compared to no gain when lysine was not in the diet. It is concluded that lysine is an indispensable amino acid for young growing pigs.

THE CHOLINE REQUIREMENT OF THE BABY PIG. A. L. Neumann, J. L. Krider and B. Connor Johnson, *University of Illinois.*

Two tests, comprising twelve 48-hour-old Duroc pigs, each, were conducted in order to establish the quantitative choline requirement. The "synthetic milk" (13 percent solids basis), used as a basal ration was composed of 30 percent vitamin-free casein, 37.4 percent cerelose, 26.6 percent lard, and 6 percent salts, plus vitamins. Two mg. sulfasuxidine were fed per liter of diet to inhibit intestinal synthesis. In test 2 each pig received 0.25 ml. Reticulogen daily. In test 1, pigs were individually fed levels of 0.0, 0.05, 0.10, and 0.20 percent choline (dry matter basis) in the diets. Average weight gains, expressed as a ratio of final weight to initial weight, and average 56 day weights, were 8.08 (29.7 lb.), 9.53 (33.6 lb.), 11.69 (38.7 lb.), and 9.22 (33.8 lb.) respectively. Histological examination of the livers showed abnormally heavy fatty deposition in the basal pigs but this condition was less severe in pigs fed 0.05 percent choline and absent on the two higher levels. In test 2, 6 pairs were fed by the equal feed method. One pig of each pair was fed the basal ration+0.05 percent choline while the pair-mate was fed the same ration+0.10 percent choline. All pigs on both choline levels made excellent gains, averaging 46.9 and 47.9 lb. respectively at 56 days, or 13.33 and 13.70 times their average initial weights. Although no significant differences were observed in gains or in liver condition, the pigs on the 0.10 percent level were again more uniform, thriftier and sounder. The level of choline required for optimal growth and freedom from fatty livers in baby pigs lies between 0.05 and 0.10 percent of the dry matter in the diet.

THE EFFECT OF THYROPROTEIN ON GROWTH, FATTENING AND CARCASS QUALITY IN SWINE. T. W. Perry, W. M. Beeson and F. N. Andrews, *Purdue Agricultural Experiment Station.*

Different combinations of thyroprotein and thiouracil were fed to 96 head of purebred Duroc hogs in two separate experiments to determine the effect of these substances on the growth and development of swine. The pigs were started at an average weight of 40 pounds and fed a basal ration composed of corn 69 percent, wheat 20 percent, Purdue Supplement No. 5 10 percent and minerals 1 percent. In the summer of 1947 thyroprotein was mixed in the basal ration at levels of 0.0088 percent and 0.0132 percent. Thyroprotein was fed in another group at the rate of 0.0088 percent until the pigs reached 150 pounds in weight and then changed to 0.1 percent thiouracil until market weight. Thyroprotein fed at the 0.0088 percent level during the summer period had no significant effect on rate of growth or carcass characteristics. The pigs receiving 0.0132 percent thyroprotein gained 14 pounds more ($P<0.05$) in the 104 days and required the same amount of feed per unit of gain as the control group. The hogs receiving the higher level of thyroprotein had significantly longer carcasses and heavier loins than the controls or the thiouracil group. Adding 0.1 percent thiouracil to the diet when the hogs averaged 150 pounds in weight depressed the rate of growth. Hogs fed thiouracil had significantly shorter carcasses and shorter legs and smaller pastern circumference than the hogs receiving thyroprotein. In the winter trial 1947–1948 thyroprotein was mixed in the basal ration at levels of 0.0088 percent, 0.0132 percent and 0.0176 percent. At the end of 95 days the hogs were 10, 17, and 27 pounds heavier respectively than the control. Carcass measurements indicated that the group receiving 0.0176 percent thyroprotein had significantly greater chest depth ($P<0.01$) than the other groups.

SOLVENT EXTRACTED COTTONSEED MEAL AS A PROTEIN CONCENTRATE FOR PIGS IN DRY LOT. W. L. Robison, *Ohio Agricultural Experiment Station.*

A solvent extracted cottonseed meal which was low in free-gossypol and supposedly non-toxic was fed with yellow corn, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot. Additions of (1) dried blood, (2) dried distillers' solubles, (3) a combination of dried blood and condensed fish solubles, (4) a combination of dried blood and dried distillers' solubles, and (5) a combination of dried distillers' solubles and 60 percent protein meat scraps ranked in the order named in increasing the rapidity and efficiency of the gains. The pigs fed the ration containing distillers' solubles and equal amounts of protein from meat scraps and cottonseed meal gained 63 percent faster and required 18 percent less feed per unit of gain than those fed the basal ration. Nevertheless those on this ration and others on one in which soybean oil meal replaced the cottonseed meal gained 1.19 and 1.42 pounds daily a head and required 402 and 365 pounds of feed per 100 pounds of gain, respectively. No pigs on cottonseed meal died but after 8 weeks some developed scabby skins. The skin was believed to be inflamed by the excretions. In a second trial pigs fed cottonseed meal treated with a solution of iron sulfate developed no skin trouble and made much faster and more efficient gains than those fed the untreated meal. When the cottonseed meal was treated with iron it gave results more closely approaching those from soybean oil meal.

THE EFFECT OF CERTAIN SUPPLEMENTS UPON REPRODUCTION AND LACTATION PERFORMANCE OF RATS FED NATURAL AND PARTIALLY PURIFIED RATIONS. O. B. Ross, W. E. Swank, Ray J. Ohman, and R. W. MacVicar, *Oklahoma A. & M. College.*

A practical swine ration composed of corn, soybean meal and 5 percent alfalfa supplemented with all the known B-complex vitamins, cod liver oil and minerals was fed to female rats to study reproduction and lactation performance. Supplements tested included Wilson's 1:20 liver concentrate powder, alcohol fractions of this liver powder, injectable liver extract (Lederle), alfalfa leaf meal, alcoholic fractions of alfalfa meal, vitamin free test casein,

fish solubles and anthranilic acid. An attempt was also made to formulate a better assay ration for testing various supplements. The active factor needed for optimum reproduction and lactation for the rat was found to be present in Wilson's 1:20 liver powder and in fish solubles. Vitamin test casein, when fed as a supplement to corn with all known vitamins added, was found to support normal reproduction but was inadequate for lactation. The alcoholic fractions of liver powder which were tested indicated that the unknown factor was readily soluble in 70 percent ethyl alcohol, less soluble in 95 percent ethyl alcohol and was not completely adsorbed by Norit. Anthranilic acid apparently was not the active factor. The active factor in liver powder was soluble in water, stable to moderate heating (50–60° C.), stable to mild acid and alkaline conditions and stable to oxidation when exposed to air.

EFFECT OF RATION UPON SOME CONSTITUENTS OF BLOOD AND MILK OF HEREFORD COWS AND THE BLOOD OF THEIR CALVES. O. B. Ross, W. J. Van Arsdell and R. W. MacVicar, *Oklahoma A. & M. College.*

Three lots of Hereford cows (3 per lot) were wintered on weathered prairie hay, and the cows of each lot fed the following supplements daily: Lot 1, 5 pounds of alfalfa hay, lot 2, 2.5 pounds of alfalfa hay and 1.0 pound of cottonseed cake; lot 3, 1.8 pounds of cottonseed cake. These rations provided a daily carotene intake for the three lots of 110, 70 and 35 mcg., per pound of body weight respectively. Blood samples were taken from each cow for chemical analysis at weekly intervals prior to calving, each day for the first 10 days and the 20th and 30th day following parturition. The calves were bled before nursing, every four hours for 24 hours, daily for 10 days and the 20th and 30th day. Carotene, Vitamin A, ascorbic acid and inorganic phosphorus were determined on the blood plasma of both cows and calves. Colostrum and milk samples were obtained for carotene and vitamin A determinations. The lowest plasma carotene levels observed in each of the lots occurred on the third or fourth day of lactation. The plasma carotene levels for the cows of lots 1, 2 and 3 at calving and at the date the lowest level was observed were respectively: 95 and 58, 59 and 41 and 41 and 30 mcg., per 100 ml. of plasma. The plasma vitamin A levels followed essentially the same pattern as those of carotene. During the first ten days, maximum plasma carotene values of the calves were found to occur on the second to the fourth day of age and maximum vitamin A values were found on the third to fifth day of age. The carotene content of colostrum of the three lots was 29, 36 and 24 mcg., per 100 ml. respectively. The vitamin A level of colostrum for the respective lots was 114, 37 and 97 mcg., per 100 ml.

THE MAGNITUDE OF CERTAIN GROSS SOURCES OF VARIABILITY IN DIGESTIBILITY DATA. Burch H. Schneider, Henry L. Lucas and Mary Ann Cipolloni, *West Virginia University and University of North Carolina.*

Digestibility data obtained with cattle, sheep, swine and horses and published by 932 authors, who used 2402 samples of 194 feeds and conducted 4629 trials, were statistically analyzed. For each animal species and in each of five feed classes, hays, other dry roughages, green roughages, silages, and concentrates, components of variance were estimated for the following variance sources: between feeds (F), between authors within feeds (A), between samples within authors (S), and between trials within samples (T). F depends on what feeds are analyzed. A, S, and T, but not F, are sources of error. In protein digestibility, the average components of variance for A, S, and T accounted for 56, 33, and 11 percent of the total error variance, respectively. Corresponding percentages for T.D.N. were 47, 38, and 15. Proximate nutrients all gave similar relative values. Components for A and S were not related to animal species, feed class, or whether digestibility was with feeds, fed alone or "by difference." Components for T appeared to be unaffected by animal species, but there was a significant feed effect and components for digestibility "by difference" were over twice those for feeds fed alone. Thirty to 50 percent of the A and S variability was associated with variations in proximate compositions. The major limitation for accuracy of an average digestion coefficient is the number of investigators. The number of samples studied by each investigator is less important. The number of trials per sample is unimportant. These facts have great implications

in summarizing existing data and in setting up efficient projects to obtain additional digestibility data.

DEHYDRATED SWEET POTATOES AS A CARBOHYDRATE FEED FOR FATTENING SWINE. Clifton B. Singletary, *Louisiana Agricultural Experiment Station.*

Three consecutive winter experiments involving the use of eighty-one pigs were conductd in fattening pigs on dehydrated sweet potato meal fed at different levels in comparison with corn. The average initial weight of the pigs was 115 pounds and they were finished at approximately 225 pounds. The sweet potato meal fed in 1947 and in 1948 was of excellent quality, being made from sound, washed cull potatoes of Porto Rico variety. The proportions of corn and dehydrated sweet potato meal fed were as follows: Lot 1—corn; lot 2—corn 2 parts, sweet potato meal 1 part; and lot 3—corn 1 part, sweet potato meal 2 parts. Each lot received a protein supplement consisting of tankage, soybean oil meal and alfalfa leaf meal. The sweet potato feed averaged 89 percent the value of corn in 1948 and 88.7 percent in 1947. In 1948 the hogs fed corn and dehydrated sweet potatoes made higher gains than on corn alone but required more feed per pound of gain. In 1946 the potato meal made from low grade material was worth only 66 percent as much as corn. At 1947 prices the dehydrated potato meal was a more economical feed than shelled corn. Pigs made satisfactory gains where the proportion of sweet potato meal did not exceed from 1/3 to 1/2 the total ration. All carcasses graded firm and showed a desirable finish. Pigs that received a heavy sweet potato ration required nearly twice as much protein supplement as did pigs receiving an all corn ration.

THE AMINO ACID CONTENT OF MEAT AND MEAT PRODUCTS. Robert J. Sirny and C. A. Elvehjem, *University of Wisconsin.*

Microbiological methods have been used for the determination of the essential amino acids in meats and meat products. One of the criteria used to check the reliability of these methods has been the use of two or more microorganisms, wherever possible, for the assay of each of the amino acids. Accordingly, procedures have been employed which utilize *Lactobacillus delbruckii*-3 and *L. arabinosus* 17-5 for the assay of isoleucine, leucine, phenylalanine and valine, *L. delbruckii* 3 and *Leuconostoc mesenteroides* P-60 for arginine and histidine, *L. mesenteroides* and *Streptococcus faecalis* R for methionine, *L. arabinosus* and *S. faecalis* for tryptophan, *S. faecalis* for threonine and *L. mesenteroides* for lysine. The excellent agreement generally obtained with the different organisms, as well as certain instances of disagreement in the phenylalanine determinations, will be discussed. The content of these essential amino acids in various cuts of meat from different species and in various animal organs will be presented. The striking similarity between muscle tissues from different species with respect to their content of these amino acids will be indicated, together with differences which were found between muscle tissues and organs for certain of the amino acids. Preliminary work on the determinations of five non-essential amino acids, i.e., aspartic acid, glutamic acid, glycine, proline and tyrosine, will be discussed. Through the use of all the data obtained so far it has been possible to account for approximately 80 percent of the total amino acid content of meat.

CARCASS COMPOSITION AND NITROGEN BALANCES OF SWINE FED THIOURACIL. S. W. Terrill, T. S. Hamilton, W. E. Carroll and J. L. Krider, *University of Illinois.*

To determine the effect of 0.15 percent thiouracil on carcass composition, 4 pairs of Duroc barrows and 3 pairs of Chester White barrows were pairfed for equal gains during a 4-week period, were slaughtered, and the right half of each carcass was divided into mechanically separable lean, fat, bone and skin. Lean and fat samples were analyzed for dry matter, ether extract, and total nitrogen. Neither the physical nor the chemical carcass composition was modified significantly by the thiouracil-feeding. Slaughter data, cutting yields, and carcass measurements were obtained from 34 barrows in 3 experiments (control vs. 0.15 percent thiouracil). Barrows fed 0.15 percent thiouracil had significantly heavier thyroids, shorter legs, and shorter and thicker carcasses than controls. Little difference was noted in thickness of back-

fat, cutting yields, carcass grade, and carcass firmness. Thiouracil barrows averaged about 1 percent lower in dressing percentage (odds 1:17). Nitrogen balances were determined on 6 pairs of Duroc barrows during the second and third weeks of thiouracil ingestion. Compared with the controls the pigs fed 0.15 percent thiouracil retained significantly more nitrogen, gained at a very significant increased rate during the 10-day collection period, but retained significantly less nitrogen per pound of gain. The body gains of controls were calculated to contain about 2 percent more protein than gains by the test pigs. No significant differences in apparent digestibility of nitrogen occurred.

EFFECT OF THIOURACIL ON RATE AND EFFICIENCY OF GAINS OF SWINE. S. W. Terrill, J. L. Krider, W. E. Carroll and T. S. Hamilton, *University of Illinois.*

Forty-one Duroc barrows were used in a series of paired-feeding tests of 6 weeks duration to determine the optimum level of thiouracil to include in the ration of fattening swine weighing 140 to 180 pounds initially. In the first test, 0.2 percent thiouracil produced significantly more rapid gains than 0.1 percent thiouracil. In the second test, 0.15 percent and 0.25 percent thiouracil promoted equal gains. In a trio-feeding test, pigs fed 0.15 percent thiouracil gained more rapidly than pigs fed 0.2 percent thiouracil (odds 1:18) and pigs on either level of the drug gained at highly significant increased rate over controls. In a group-feeding test of 6 weeks duration (control vs. 0.15 percent thiouracil, 15 pigs per lot), the thiouracil pigs (1) required 63 to 75 pounds less feed per 100 pounds gain than controls when fed for 3 to 6 weeks, (2) showed no significant increase in cumulative gains over controls, but gained significantly slower during the fifth and sixth weeks, and (3) consumed an average of 1.5 pounds less feed per pig daily than controls. In a test in which 12 Duroc barrows were full-fed individually for 6 weeks (control vs. 0.15 percent thiouracil), the thiouracil pigs required 54 to 75 pounds less feed per 100 pounds of gain than controls when fed for 3 to 6 weeks (highly significant), (2) showed no significant increase in cumulative gains over controls, but gained significantly slower during the fifth and sixth weeks, and (3) consumed an average of 1.7 pounds less feed per pig daily than controls (highly significant).

COMPARATIVE EFFICACY OF SOME VITAMINS D IN HEALING MAMMALIAN RICKETS. Byron H. Thomas, Gleason M. Diser and Lester Yoder, *Iowa State College.*

The use of one or another of the known vitamins D in supplementing farm rations has increased markedly in recent years. The vitamins D differ in their capacity to prevent or cure rickets. Yoder (1934) reported the production of a new vitamin D by chemical activation. This was believed to be cholesterilene sulfonic acid. Later Yoder, Thomas and Lyons demonstrated this vitamin preparation to be more efficaceous than codliver oil or irradiated ergosterol in preventing rickets in chicks. Preparations made by the antirachitic sulfonation procedure are identified by the collective term "Chemosterol-D." Several forms of it, namely, cholesterilene sulfonic acid and certain basic salts of it, and a less refined preparation made from wool grease were studied. Their efficacy in curring experimentally induced mammalian rickets was compared to that of codliver oil, irradiated ergosterol, and irradiated 7-dehydrocholesterol. The relative capacity of these materials to heal rickets was determined by feeding to rats a rachitogenic ration supplemented with several levels of each vitamin D. The healing that occurred in each of the ten rats in each test-group was scored and comparisons made. The healing induced by the various supplements differed markedly. Judging from the results of feeding several comparable multiples of the minimum amount of each supplement required to produce a narrow continuous line of healing in the rachitic metaphyses of rats, the cholesterilene sulfonic acid produced most rapid healing, codliver oil the least, whereas the others produced intermediate responses.

PURIFIED DIETS FOR STUDYING AMINO ACID REQUIREMENTS OF RUMINANTS. Walter Thomas, J. K. Loosli, H. H. Williams and L. A. Maynard, *Cornell University.*

Purified milk diets were formulated for young goats and purified dry diets for mature

goats and sheep for use in studying the amino acid requirements of these ruminants. Diets containing 25 percent of sucrose or 12 percent of acid hydrolysate of casein caused diarrhea which was cured or prevented by adding 2.5 percent of dried brewers' yeast. The casein hydrolysate diets were particularly unpalatable but anise oil was effective in improving the palatability and giving satisfactory feed intakes. Nitrogen balance studies were made to compare urea, glycine, casein, and casein hydrolysate as the only nitrogen source in purified diets when fed at 7 and 10 percent of protein equivalent. Casein and acid hydrolysate of casein with tryptophan added back gave identical biological values of 86 and 84 when fed to growing lambs at levels equivalent to 7 and 10 percent protein, respectively. The essential amino acid content of the feeds and of rumen and excreta samples were determined on the above diets as a further measure of the rumen synthesis of the essential amino acids.

THE USE OF DRIED WHEY WITH WHEY FERMENTATION SOLUBLES, DEHYDRATED ALFALFA MEAL, FISH SOLUBLES, AND MEAT SCRAPS IN DRYLOT RATIONS OF WEANLING PIGS. R. F. Poucke, F. W. Hill and N. E. Rodgers, *Western Condensing Company.*

Two feeding tests were conducted to study the supplementary value of dried whey with whey fermentation solubles, dehydrated alfalfa meal, meat scraps, fish solubles and certain combinations of these products for pigs from weaning to 100 pounds in drylot. In the first test, a basal ration containing 63.5 percent yellow corn, 34.0 percent soybean meal, complete mineral mixture, the 6 B-complex vitamins (riboflavin, niacin, thiamine, pyridoxine, pantothenic acid, choline), and vitamin A and D oil was fed. All rations fed contained 20 percent crude protein. Pigs receiving the basal ration plus 4 percent dried whey with fermentation solubles gained more rapidly and economically than those fed the basal ration. Pigs receiving a combination of fish solubles and meat scraps gained more slowly than those receiving 4 per cent dried whey with fermentation solubles but gains were produced more economically. In the second test, the basal ration was altered to include 5 percent alfalfa meal. Rate of growth was increased .25 pounds per pig per day when dried whey with whey fermentation solubles and meat scraps were added to the basal ration and 18 percent less feed was required to produce 100 pounds of gain. Slightly increased rate of growth was obtained upon addition of whey with fermentation solubles to the basal, and improved haircoat and skin condition were observed. Data will be reported on weight gains, efficiency of feed utilization and deficiency symptoms observed in all lots of pigs.

OBSERVATIONS ON PYRIDOXINE DEFICIENCY IN BABY PIGS. A. C. Wiese, W. P. Lehrer, Jr., June Anderson, O. F. Pahnish and P. R. Moore, *University of Idaho.*

Two-day old pigs were placed on a synthetic diet consisting of vitamin-free casein, lard, cerelose, mineral mixture, and supplemented with all known synthetic vitamins with the exception of pyridoxine. The animals developed the following symptoms: poor appetite, poor growth, spastic gait, incoordination of the muscles, epileptiform fits, and the apparent impairment of eyesight. The urinary excretion of pyridoxine fell to a low level. The supplementation with pyridoxine cured all symptoms with the exception of the impairment of eyesight.

Pasture and Range Section

G. O. Mott, *Chairman*

GRASS TETANY IN EWES GRAZING WINTER OATS. B. F. Barrentine, *Mississippi Agricultural Experiment Station.*

Grass tetany was observed in a group of ewes grazing winter oats. The symptoms are identical with those that have been observed in grass tetany of cattle. Extreme hypomagnesemia and very low serum phosphorous values were observed. The serum calcium was

essentially normal. Seven out of nine lactating ewes were affected, three died and four responded to injections of calcium and magnesium gluconate. Only lactating ewes were affected. The relationship of the high protein content of lush forage to the etiology of grass tetany is discussed.

EFFECT OF LEVEL OF WINTERING OF STEER CALVES UPON SUBSEQUENT SUMMER GAINS. A. E. Darlow, O. B. Ross and D. F. Stephens, *Oklahoma A. & M. College.*

This study was conducted during a 5-year period with 280 steer calves. Winter rations fed in dry lot were: 1. cottonseed meal, silage and oats; 2. cottonseed meal and silage; 3. cottonseed meal and prairie hay. Cotton seed meal and prairie hay was fed to steers wintered in a four acre trap on the range and cottonseed meal was fed as a supplement to steers wintered on the range. The length of the wintering period was 150 days. The calves were turned to one large pasture in April and grazed for approximately 100 days. At that time part of the steers were placed in dry lot and full fed for approximately 90 days and the remainder continued on grass and marketed as stocker steers. Atlas sargo silage was the most satisfactory roughage for wintering steer calves in dry lot. Calves fed silage (ad lib.) supplemented with cottonseed meal made approximately 45 percent more winter gain than steers fed prairie hay (ad lib.) and cottonseed meal. Steers which gained the most during the winter gained the least on grass. Although greater summer gains on grass were made by steers that were wintered at the lower levels, the final weight in either the fed lots or those on grass was less than those wintered at the higher level. The most profitable method of producing stocker yearling steers in this study was to winter the calves at a low level with cured range grasses as the roughage and cottonseed meal and providing ample herbage during the summer.

MICHIGAN'S COW AND FEEDER CALF PROGRAM FOR UTILIZATION OF PASTURE AND ROUGHAGE. W. L. Finley, G. A. Branaman, G. L. Blank and G. F. Moxley, *Michigan State College.*

Because of favorable soil, climate and geographic location Northern Michigan lends itself to the production of high quality pasture and roughage. Marketing this roughage with efficiency, the limited farm labor supply, and the value of organic matter in maintaining soil fertility are factors emphasizing the need for this program. Commercial cattle herds vary in size from ten to one hundred fifty head of breeding cows. Many foundation cows are of western origin. Other herds have been developed from native Shorthorn foundations. They have been converted to Hereford herds by using good Hereford bulls. Some herds are maintained by the selection of heifer calves while others depend upon western cows for replacements. Bulls from Michigan Hereford herds and the Wyoming Hereford Ranch sire the calves sold each fall. Farmers of central and southern Michigan produce corn and small grains with efficiency. They prefer selling these crops through livestock. The calf crop largely dropped in April, is sold in October through cooperative consignment sales in Ogemaw and Otsego counties. Calves are sorted into uniform lots and are sold at auction. The cooperative sales have provided a desirable market outlet, they have served as an educational hireling and have developed prestige among cattle breeders. By selling the calf crop mature herds may be maintained upon pasture and roughage. The program fits Northern Michigan and affords a desirable market for the roughage which farmers in that section produce.

FURTHER INVESTIGATIONS OF THE RELATIONSHIP BETWEEN CHEMICAL COMPOSITION, DIGESTIBILITY AND PALATABILITY OF PASTURE FORAGES. R. M. Forbes and W. P. Garrigus, *Kentucky Agricultural Experiment Station.*

In the second year of pasture investigations utilizing the lignin ratio technique, with steers and wethers as experimental subjects, the relationship between lignin content and digestibility of dry matter was found to be similar to that reported previously. Forages grazed

this season were Lincoln bromegrass, orchard grass, Kentucky 31 fescue, timothy, red top, alfalfa, Kentucky bluegrass, and ladino clover by wethers; alfalfa, ladino clover, Kentucky bluegrass, orchard grass and Kentucky 31 fescue by steers. Palatability as, judged by dry matter intake, tended to decrease as maturity and lignin content of the forage increased, but there was a large variation in intakes between forages that was not apparently related to lignin content. Digestion trials, conducted to establish the accuracy of the lignin ratio technique led to variable results. In all cases, the lignin recovered in the feces was greater than the amount fed, the excess ranging from less than 1 percent to about 23 percent with an average of about 14 percent.

PASTURE FOR SWINE. J. L. Gobble, R. C. Miller, P. T. Ziegler and F. L. Bentley, *The Pennsylvania State College.*

During the summer of 1944 groups of 5 pigs each on ladino clover pasture were fed by pairs on rations of ground corn and a protein supplement containing 12, 15, and 18 percent of crude protein. The ration containing 12 percent of protein was equal to the higher levels of protein. Corn and pasture does not provide for maximum growth. In 1945, 40 pigs were started on one acre of ladino and another 20 pigs were put on dry lot and fed fresh cut ladino clover as soilage. All pigs were fed corn and supplement free choice. After 28 days 20 of the pigs on ladino clover pasture were put on dry lot and fed corn and supplement. The others were continued as before. During the first 28 days the ladino clover pasture gave faster gain and more economical feed utilization than soilage. Later in the test soilage gave a slightly faster rate of gain than either of the other two, but required more protein supplement than the pasture group but less than the dry lot. In 1946 three lots were set up on ladino pasture, orchard grass pasture, and dry lot, self-fed free choice on corn, protein supplement, and a simple mineral mixture. The ladino clover pasture gave slightly faster gains and the pigs required less feed, per unit of gain. In 1947 test lots were set up, two on clover and orchard grass and two on orchard grass. A soybean oil meal supplement was superior to soybean meal and tankage.

EFFECTS OF CONCENTRATE SUPPLEMENTS ON STEERS FATTENED IN THE GREEN LOT. Ralph W. Kidder, *Florida Agricultural Experiment Station.*

Results of a feeding trial with 50 grade Brahma steers grazing 20 acres of St. Augustine grass from October 1947 to May 1948, indicate that without supplementary concentrate feeds, 760 pound steers will consume an average of 90 pounds of grass each per day, while similar lots receiving ground snapped corn will consume as much as 80 pounds of grass daily in addition to five pounds of ground snapped corn. When the concentrate supplement is blackstrap molasses in a self feeder the steers will consume between six and one-half to seven pounds of molasses but only 50 to 60 pounds of grass each per day. The estimation of amount of grass consumed is based on the total digestible nutrient requirement for maintenance plus gains and the nutrient content of the feeds including grass. When steers gain 1.21 pounds per day while grazing at the rate of 2.5 head per acre, the pasture is producing 3.025 pounds of increased weight per acre daily or an average of more than 1100 pounds per acre annually including the winter season when the pasture growth is less than during the summer.

THE VALUE OF ADDING GROUND ALFALFA HAY TO A CONCENTRATE MIXTURE FED WITH PRAIRIE HAY IN A RATION FOR DAIRY COWS. A. H. Kuhlman and H. W. Cave, *Oklahoma A. & M. College.*

When high protein concentrates are scarce dairy farmers are often unable to prepare a home-mixed concentrate mixture which will properly supplement the protein of a non-legume roughage. Three feeding trials have been conducted on the 90-day double reversal plan with a total of 37 dairy cows to determine the value of using ground alfalfa hay in a concentrate mixture fed with prairie hay. The control ration consisted of prairie hay and a concentrate mixture composed of 350 pounds No. 2 ground yellow corn, 200 pounds ground oats, 200

pounds wheat bran, 250 pounds cottonseed meal and 10 pounds each of ground limestone, steamed bonemeal and salt. The experimental ration, in which 300 pounds ground No. 2 alfalfa hay replaced 30 percent by weight of the corn, oats, bran and cottonseed meal of the control ration, maintained milk yields and body weights satisfactorily. Average daily yield of 4 percent fat-corrected milk per cow was 27.5 pounds on the control ration and 27.2 pounds on the experimental ration. Average feed requirements for 100 pounds of 4 percent milk were 52.45 pounds concentrates and 63.89 pounds prairie hay on the control ration, and 58.38 pounds concentrates and 64.96 pounds prairie hay on the experimental ration. Ground alfalfa hay as used in this experiment is worth $25.14, $38.73 and $52.32 per ton, if the concentrates which it replaces, respectively cost $2.00, $3.00 and $4.00 per hundred pounds and prairie hay costs $16.00 per ton.

THE VALUE OF PASTURE AS A SUPPLEMENT FOR FEEDING YOUNG PIGS. G. W. Vander Noot, M. A. Sprague and W. C. Skelley, *New Jersey Agricultural Experiment Station.*

A trial was conducted during the summer of 1948 to determine the value of alfalfa, brome grass, rape, and soybeans as part of the diet of swine, supplemented with approximately 1 1/4 pounds of concentrates for each 100 pounds of liveweight. Three lots of 20 pigs, each averaging 41 pounds, were fed a ration of corn and meat scraps, and were maintained on 2 half acres of alfalfa; alfalfa for 35 days and then rape; brome grass for 35 days and then soybeans. Eight additional pigs were full fed the above ration in drylot, while eight others received a balanced ration. The average daily gain per pig on alfalfa, alfalfa and rape, and brome grass and soybeans, was 0.34, 0.41, and 0.42 pounds, respectively. The pounds of feed to produce one pound of gain was 1.74, 1.53 ,and 1.78. The pigs in drylot fed the pasture ration required 10.87 pounds for each pound of gain; the pigs fed a balanced ration required 2.99 pounds of feed for each pound of gain in weight, while gains of these two lots were 0.83 and 1.19 pounds per pig per day, respectively. The cost (based on retail feed prices) of each pound of gain for the pigs on alfalfa was 8.7¢; alfalfa and rape, 7.6¢; brome grass and soybeans, 8.9¢; and for those pigs fed a balanced ration in drylot it was 14.9¢ compared to 54¢ for the drylot pigs fed the pasture ration.

Physiology Section

A. V. Nalbandov, *Chairman*

EFFECT OF THYROPROTEIN AND THIOURACIL ON THE CONCENTRATIONS OF CAROTENE AND VITAMIN A IN THE BLOOD OF DAIRY CALVES. R. S. Allen, G. H. Wise and N. L. Jacobson, *Iowa Agricultural Experiment Station.*

A study was made of the effect of iodinated casein "Protamone" and thiouracil on carotene and vitamin A levels in the blood plasma of five calves, one Guernsey and four Jerseys. A level of 1.5 grams of iodinated casein per 100 lbs. body weight appeared to have little effect on the levels of carotene and vitamin A in the blood plasma when administered to calves receiving alfalfa hay that provided carotene in sufficient quantities to maintain concentrations above the critical level. The effect of increased iodinated casein administration, in the case of calves receiving adequate carotene, appeared to influence the general health of the animals before any noticeable change in the concentration of carotene and vitamin A in the blood plasma became evident. At a marginal level of carotene intake (2500–3000 I.U. per 100 lbs. body weight) the acceleration of metabolic rate resulting from feeding iodinated casein in quantities ranging from 1.5 to 3.0 grams per 100 lbs. body weight, was accompanied by suppression of carotene and vitamin A levels in the blood. In this study there was no evidence of increased conversion of carotene to vitamin A, as revealed by the levels in blood plasma when iodinated casein was fed. Though the plasma vitamin A level increased slightly from

administration of thiouracil at the rate of 5 to 10 grams per 100 lbs. body weight the increase is of questionable significance.

EFFECTS OF THIOURACIL AND SIMILAR COMPOUNDS ON FEEDER LAMBS. E. R. Barrick, F. N. Andrews, W. M. Beeson and Claude Harper, *Purdue University.*

Investigations have been conducted with feeder lambs for three years on the effects of thiouracil and similar drugs on rate of gain, feed consumption, feed efficiency, thyroid size and histology and various components of the blood. The drugs were administered in the concentrate in 3 experiments and graded doses of the drugs were administered in capsule or tablet form in 4 experiments. These experiments showed the following: The amount of thiouracil required to cause marked changes in the thyroid gland was quite variable. Feeding 0.18 gm. thiouracil per lamb daily for 84 days in one experiment caused more stimulation of the thyroid gland than 0.21 to 0.63 gm. for 84 to 126 days in two other experiments. It required 3 grams of thiouracil in tablet form to be effective in one experiment. Low levels of thiourea had marked effects on the thyroid gland. Rate of gain, and feed efficiency were not significantly affected by thiouracil administered in the feed at levels of 0.18 to 0.64 gm. per lamb daily. Feed consumption tended to be reduced when 0.4 gm. or more of thiouracil was incorporated in the daily feed. An increase in blood plasma cholesterol was shown in most cases where animals were administered approximately 1.0 gm. or more of thiouracil. Thiourea and high levels of thiouracil appeared to interfere with the conversion of carotene to Vitamin A. Blood sugar, hemoglobin, erythrocyte and leukocyte numbers and ascorbic acid content of the blood plasma were not noticeably affected by thiouracil treatment.

THE ABSORPTION OF CAROTENE AND VITAMIN A FROM VARIOUS LEVELS OF THE GASTROINTESTINAL TRACT OF SHEEP. E. R. Barrick, F. N. Andrews and J. F. Bullard, *Purdue Agricultural Experiment Station.*

The rate of absorption of vitamin A and carotene from different levels of the gastrointestinal tract was studied by administering vitamin A and carotene solutions orally and by way of fistulas in the rumen, small intestine, caecum and colon of western feeder lambs. Blood plasma carotene and vitamin A levels were followed as a measure of absorption rate. Relatively large amounts of vitamin A were required to cause a noticeable rise of vitamin A in the blood plasma. No marked change in the blood vitamin A or carotene level was observed as a result of administering vitamin A and carotene in the caecum or colon. The change in the vitamin A content of the blood was much slower and less pronounced following the administration of carotene than in the case of vitamin A. Only small amounts of carotene were found in the blood following the administration of massive doses of carotene. Vitamin A given orally was absorbed at about the same rate as that placed in the rumen. Following injection of vitamin A into the small intestine the vitamin A level of the blood increased sooner than when it was given in the rumen or administered orally; however, it did not reach as high a peak and was not maintained at an increased level for as long a period.

THE INFLUENCE OF BODY SIZE OF DAIRY CATTLE ON THEIR REACTION TO HIGH AMBIENT TEMPERATURES. Samuel Brody, A. C. Ragsdale and H. J. Thompson, *University of Missouri, and United States Department of Agriculture.*

Remarkable difference in the reactions of individual dairy cows to ambient temperatures above 75° F. were observed in the Psychroenergetic, or Climatic, Laboratory, in Columbia Mo. Many factors are involved in body temperature regulation of which body size appears to be important. The curves relating rectal temperature, milk production, feed consumption body weight and some cardiorespiratory activities to ambient temperatures indicate that thermal distress begins at lower temperatures and increases at higher rates with increasing ambient temperatures in large than in small cows. This is not unexpected because heat dissipation is by way of the body surfaces; and since the amount of surface per unit body weight de-

creases with increasing body weight, the rate of heat dissipation per unit weight slows down with consequent earlier and steeper rise in body temperature in large than in small animals. The critical temperature—that is, the temperature which begins to exert a definitely depressing effect on the productive process—is 5° to 10° F. lower for the large (75 to 80° F.) than for the small (80 to 85° F.) cows. A particularly dramatic, but perhaps fortuitous, event was the abortion of 4½ and 6 month fetuses by two of the largest animals (with the highest rectal temperatures) 2 to 3 days after a 30-hour exposure to a 100° F. temperature. Is it possible that the abortions were caused by the thermal death of the fetus? All were Brucellosis free. Perhaps unexpected was the rise in the milk-fat percentage with rising temperature, that is, with declining milk yield, especially in the large cows. The possible involved neuro-endocrine mechanisms will be outlined.

THE EFFECTS OF PROGESTERONE IN ALTERING THE ESTRUS CYCLE OF THE COW. R. E. Christian and L. E. Casida, *University of Wisconsin.*

Four yearling heifers were used in this study. Treatment was started on the fourteenth day of the estrual cycle and consisted of fourteen daily injections of progesterone in corn oil. Two different daily dosages of progesterone were used, 50 mg. and 25 mg. Two or more trials were run on three of the animals with a rest interval of one estrual cycle. Fifty milligrams of progesterone daily suppressed heat and prevented ovulation during the entire treatment period. All heifers treated with 50 mg. daily came into heat 5–6 days after the end of treatment. The succeeding estrual cycles in all cases were of normal length. Twenty-five milligrams of progesterone daily suppressed heat in all cases but did not prevent ovulation in two of four cases. This lower dosage of progesterone appears to have been close to the threshold of the amount needed to prevent ovulation and produced much more variation in the reaction of the heifers. Of the four heifers treated with 25 mg. daily, one reacted similar to that when treated with 50 mg. daily; one heifer returned to the time schedule of her original estrual cycle and the other two heifers, which ovulated during treatment, developed cystic ovaries (as determined by palpation) a few days after the end of treatment.

ON THE NATURE OF THE METABOLIC REGULATOR IN SPERMATOZOA. D. Ghosh and Henry A. Lardy, *University of Wisconsin.*

The active component of the metabolic regulator in semen occurs in at least 3 forms; part of it is free, part is conjugated but soluble, while a part is bound to the sperm cell. The free active component may be liberated in vitro by mild alkaline hydrolysis. Epididymal spermatozoa contain no free regulator as shown by a yeast assay but activity is present after hydrolysis. In freshly ejaculated semen the substance is present in high concentration in spermatozoa but low in the seminal fluid. The activity of the fluid increases considerably on storage of the semen for a few hours. The regulator thus seems to occur in a bound inactive form in the sperm cells from which it is progressively liberated into the seminal fluid as a result of some metabolic process started immediately after ejaculation. The regulator has been separated from bull semen in a highly purified form by subjecting the semen to alkaline hydrolysis, removing inert material by precipitation with acetone and subsequently extracting the active principle with ether from the acetone soluble fraction. Further fractionation of this extract has shown that the active compound is not a free fatty acid or a phospholipid. In highly purified form the regulator is heat labile and non-dialyzable. Purified fractions give a positive Liebermann-Burchard test. None of the pure fatty acids, steroid hormones and various other compounds tested has shown activity of the type exhibited by the activator.

INCIDENCE AND HISTOLOGY OF REPRODUCTIVE ABNORMALITIES IN THE SOW. J. A. Green and A. V. Nalbandov, *University of Illinois.*

As part of a study of impaired fertility in swine the incidence of cystic ovaries and of other reproductive abnormalities was determined at two packing houses. One sample obtained in January, 1948 at a Chicago plant included 1752 non-pregnant tracts of which 114 (6.5%)

were found to have cystic ovaries. In pregnant animals the incidence of cystic ovaries was 8.0%. In another study conducted at a Danville packing house during June and July (1948) 436 non-pregnant tracts were examined of which 18 (4.1%) were found to be cystic. In both samples the cysts varied in number from single to multiple in either or both ovaries and in size from a diameter of about 20 mm. to 40 mm. While the majority of the cysts were found to be lutenized, a more detailed discussion of the histology will be given. The nature and frequency of other abnormalities found will be presented and illustrated.

RESULTS OF INSEMINATING DAIRY COWS WITH SEMEN DILUTED WITH PHOSPHATE, CITRATE, AND ORTHO BUFFERS. Victor Hurst and J. P. LaMaster, *South Carolina Agricultural Experiment Station.*

This experiment was designed to compare the rates of conception of dairy cows bred with semen diluted with Phillips' Phosphate, Sodium Citrate (3 grams of $Na_3C_6H_5O_7 \cdot 2H_2O$ per 100 ml. of sterile water distilled over glass), and the Ortho Diluter. Fifty-seven females consisting of both heifers and cows in the Clemson herd were inseminated. Semen was used from 15 bulls varying in age from 16 months to 11 years. For any given collection day, semen from each bull was divided into all three diluters at equal concentrations. During the first third of the six-week experimental period the semen collected from each bull was used in the sequence of first in Phosphate, second in Citrate, and third in Ortho Diluter. During the two subsequent periods, the order of the use of diluted semen was changed so that by the end of the experiment all three diluters were used in the different order positions. This equalized the age factor of the semen since all semen was held up to five days for breeding purposes. The results on 65 day non-returns showed Ortho 62 percent, Phosphate 59 percent, and Citrate 58 percent non-returns on first and second services combined. Pooling the results of all three diluters, semen used up through 35 hours of age, regardless of the degree of motility over zero, gave 70 percent non-returns, and semen used over 35 hours of age gave 46 percent non-returns.

EFFECT OF COMBINED THYROPROTEIN AND ESTROGEN FEEDING UPON MILK PRODUCTION. Eugene Kauffman and C. W. Turner, *Missouri Agricultural Experiment Station.*

It has been shown by a great deal of experimental work that the feeding of thyroprotein (Protamone) in the declining stages of lactation of both dairy cattle and goats generally results in an increased yield of milk and fat varying from 10 to 30 percent or more. After some weeks however, milk secretion begins to decline again at the usual rate of persistency inherent in individual animals. Meites and Turner (Mo. Agric. Expt. Sta. Res. Bul. 415–416) presented evidence indicating that the estrogenic hormone was responsible for the increased secretion of the lactogenic hormone after parturition which stimulates milk secretion and is believed to play an important role in the maintenance of persistency of lactation. It was thought possible that the constant feeding of suitable amounts of estrogenic hormone in the form of some derivative of diethylstilbestrol might tend to maintain the secretion of the lactogenic hormone at a high level and thus hold up milk secretion on a plateau. Experiments will be reported indicating the dosages of estrogens for both cows and goats which seemed to be effective. During the past year preliminary experiments have been conducted on groups of cows and goats involving the feeding of both thyroprotein and the dimethyl ether of diethylstilbestrol throughout the declining period of lactation. The results of these observations will be presented.

A NEW REGULATOR OF METABOLIC PROCESSES IN SPERMATOZOA. Henry A. Lardy and D. Ghosh, *University of Wisconsin.*

The metabolic behavior of ejaculated and epididymal bull spermatozoa differ in several respects. Ejaculated spermatozoa exhibit a fairly vigorous respiration with or without added substrate but exhibit only a feeble "Pasteur effect," i.e., they produce lactic acid almost as rapidly in air as they do in the absence of oxygen. In contrast, epididymal spermatozoa have a comparatively low rate of respiration which is greatly increased by added substrates and

they exhibit a powerful Pasteur effect—lactate production is usually four times as great in nitrogen as in air. A study of the fundamental mechanism underlying these metabolic differences has led to the discovery of a new metabolic regulator. The regulator functions by stimulating metabolism and preventing assimilation. This principle has been made use of in a roughly quantitative assay for the regulator. The regulator occurs in a bound, inactive form in epididymal spermatozoa. Its slow liberation during storage of excised epididymides is apparently responsible for the previously reported metabolic "maturation" of stored epididymal spermatozoa. The addition of a minute quantity of purified regulator to epididymal spermatozoa stimulates the endogenous respiration by as much as 200 to 300 percent and increases the rate of aerobic glycolysis until the "Pasteur effect" is no longer exhibited. The regulator also exerts a marked stimulating effect on samples of ejaculated spermatozoa having a low endogenous rate of metabolism characteristic of epididymal spermatozoa. This effect becomes less and less pronounced as the level of endogenous respiration approaches the upper "normal" range peculiar to most specimens of ejaculated spermatozoa. The regulator is present in the semen of various other species, viz., frog, fish, rabbit, ram, boar and man.

EFFECT OF THYROID STATUS ON RESPONSE OF THE GONADS TO PREGNANT MARES' SERUM IN TWO DIFFERENT SPECIES. J. Meites and B. Chandrashaker, *Michigan State College.*

Artificially induced hypothyroidism or hyperthyroidism have generally been assumed to be unfavorable to reproductive processes, although dosage levels and species differences have often been ignored. In the experiments reported here, a constant dose of PMS was injected into immature rats and mice, and the combined weights of the seminal vesicles and coagulating glands were used to measure the gonadotropic response. Hypothyroidism was induced by feeding 0.1% thiouracil for four to twenty days and hyperthyroidism was induced by feeding thyroprotein in concentrations of 0.02 to 0.64% for ten days. In the rats almost all levels of thyroprotein decreased the effectiveness of the PMS while thiouracil increased it. In mice, contrary to the results obtained in the rats, thyroprotein increased the gonadotrophic response while thiouracil decreased it. It thus appears that, insofar as this particular response is concerned, immature rats are secreting thyroid hormone above the optimal levels while immature mice are secreting below the optimal level. Other data also indicate that the rat and mouse may respond oppositely to the same hormonal stimulus because of a difference in thyroid secretion. These results are believed to be significant since they indicate that (1) thyroprotein and thiouracil may be useful adjuncts in treating reproductive failures associated with thyroid dysfunction, and (2) species and individual differences in thyroid secretion rate should be taken into account when treating farm animals with these substances.

EFFECT OF CORPORA LUTEA ABLATION AND REPLACEMENT THERAPY WITH PROGESTERONE ON GESTATION IN GOATS. J. Meites, R. N. Hatch, F. W. Young and F. Thorp, *Michigan State College.*

Previous work by Drummond-Robinson and Asdell demonstrated that abortion followed the removal of the corpora lutea during mid or late pregnancy in eight goats. It was the purpose of this study to determine whether the administration of progesterone could replace the excised corpora lutea during the last third of pregnancy. Six goats were used in the preliminary experiment reported here, three of which served as controls. On the 100th day of gestation laparotomies were performed on all goats and the corpora lutea were carefully shelled out from the ovaries. The three controls received no further treatment, and two of these promptly aborted two days later. The third goat failed to abort and it was suspected that a corpus luteum had been overlooked. A second laparotomy was performed on the 117th day of gestation, and abortion occurred two days later. The other three goats were injected with 25 mg. of progesterone (Lipo-Lutin) daily, beginning on the day before the operation and continuing until the 149th day of gestation. On the 151st day the three goats dropped normal kids. In all six goats, the number of fetuses aborted or live kids born corresponded to the number

of corpora lutea removed. These results demonstrate that 25 mg. of progesterone daily adequately substitutes for the corpora lutea during the last third of pregnancy in goats.

THE EFFECTS OF FEEDING THYROPROTEIN (PROTAMONE) TO DAIRY CALVES. T. W. Millen, W. B. Nevens and K. E. Gardner, *University of Illinois.*

During the hot summer of 1947, six male dairy calves under 200 pounds body weight were used in a thyroprotein study. One Jersey and one Guernsey calf were fed at the rate of 1 gram thyroprotein to 75 pounds body weight. Two Guernseys received 1 gram to 25 pounds body weight. One additional Jersey received .65 gram potassium iodide daily to observe hyper-iodism. One Guernsey was kept as a control. All calves received hay and the University calf grain mixture fed ad libitum. Calves on the high rate of thyroprotein feeding exhibited lachrymation, diarrhea, and abnormally high respiratory rates, pulse rates, and body temperatures. The symptoms for calves on the lower rate were of a much lower degree. Height of withers of all calves increased during the experimental period. Calves on the high thyroprotein rate showed continuous weight losses while heart girth measurements showed little change. Calves on the lower rate showed slight weight gains as compared to the control calf. Blood hemoglobin, inorganic phosphorus, calcium, and sugar showed no changes which could be attributed to thyroprotein feeding. Blood non-protein nitrogen run by manometric procedure showed an initial drop in experimental animals but gradually returned to normal. Upon histological section the thyroid glands of all thyroprotein-fed calves showed colloid. One Guernsey receiving thyroprotein at the lower rate had a thyroid twice as large as that of the control calf.

SOME STUDIES ON TEMPERATURE ADAPTATION IN THE BABY PIG. H. W. Newland, D. P. Wallach and W. N. McMillen, *Michigan State College.*

The average temperature responses of 25 pigs under barn conditions show that the temperature of a new-born pig drops from 3° to 9° F. during the first hour after birth, with an average drop of 4° F. The sharpest drop occurred during the first 20 minutes of life, and by the time the pigs were an hour old, there was a gradual increase toward normal. The average temperature of 25 pigs observed was 98° F. at 20 minutes, 100.5° at 10 hours, 101.5° at 24 hours, and 102.3° at 48 hours of age. At 2 days of age, the pigs had practically reached the temperature of their mothers, or 102.5°. At 2 days of age the heavier pigs withstood temperatures of 34° to 36° F. with less drop in body temperature than pigs of a younger age. There was a significant correlation between the weight of a pig and its ability to adapt itself to chilling. Light pigs (under 2 pounds), because of greater surface area in proportion to body weight, must produce more heat per unit of body weight than heavier pigs and are unable to do this under severe conditions. They thus show a sharper drop in body temperature after birth, a slower recovery of normal temperature and suffer first from chilling.

SOME PHYSIOLOGICAL EFFECTS OF CLIPPING DAIRY COWS. Robert B. Price, Jr. and N. N. Allen, *University of Wisconsin.*

Observations on the effect of over-all clipping of dairy cows have been made during two summers and one winter. Half of the cows in the herd were clipped, the other half serving as controls. No difference in rectal temperature or heart rate was found between the two groups. As has been reported by others, the rectal temperature was increased on the hottest summer days, but both groups were affected alike. The average respiration rate was lower for the clipped cows, even at barn temperatures during the winter. The respiration rate was found much more sensitive than body temperature to environmental changes in temperature and humidity, being affected at a level below that causing body temperature increases. The respiratory system appears to be the most flexible of the major sources by which the cow eliminates excess body heat, adjusting its rate to that necessary to maintain normal temperature. The increased radiation from the skin resulting from clipping was apparently reflected in a lower

demand for heat elimination through the lungs and consequently a lower respiration rate. The pyrexial point apparently is reached only when the respiratory system approaches its capacity for heat elimination. The clipped animals were noticeably neater and cleaner in appearance, particularly during the winter months. The white areas of some closely clipped animals sunburned, becoming red, inflamed, and swollen right up to the margin of the pigmented areas.

THE EFFECT OF THE ADMINISTRATION OF VARIOUS FATTY ACIDS ON THE BLOOD KETONE LEVELS OF RUMINANTS. L. H. Schultz, Veral R. Smith and H. A. Lardy, *University of Wisconsin.*

In an effort to obtain some information regarding the source and site of production of blood ketones, various fatty acids were administered to goats and the total blood ketone levels were followed. Dosages of 15 cc. and 30 cc. of the liquid acids were diluted with water and administered by stomach tube. Solid fatty acids were given by capsule. Starting at the beginning of the series, acetic and propionic acids in all the dosages used caused no significant rise in total blood ketones. Butyric, caproic, caprylic and capric acids caused increases in blood ketones of 5 to 10 mg.% in all cases. Peaks were usually reached in 15 minutes for butyric acid and in one hour for the other three acids. Values returned to normal in about 3 hours. Increased dosage did not result in a proportional increase in total blood ketones. Lauric acid, oleic acid, and corn oil, administered to equivalent amounts, caused no significant rise in blood ketones. In order to check the role of rumen microorganisms in this ketone body production, acetic and butyric acids were injected into the blood stream. Acetic caused no change in the blood ketone levels. Ten cc. of butyric administered intravenously caused an increase comparable to 15 cc. put into the rumen. The highest level was reached in 15 minutes, with values dropping back to normal in about one hour. These data would indicate that butyric, caproic, caprylic and capric acid may act as precursors of the blood ketones.

THE EFFECT OF THYROIDECTOMY PLUS THIOURACIL FEEDING ON CAROTENE METABOLISM IN THE GOAT. Veral R. Smith, R. P. Niedermeier and L. H. Schultz, *University of Wisconsin.*

Recent reports have indicated that the thyroid gland is of a major importance in the conversion of carotene to vitamin A. Male kid goats ranging in age from 41 to 61 days were depleted of vitamin A. The goats were considered depleted when the blood plasma vitamin A had dropped to 10 micrograms percent and there was a stasis of growth for 3 consecutive weeks. There were 5 kids in the experimental and 3 in the control group. The experimental group was fed thiouracil in gelatin capsules at the rate of 0.2 gram per kilogram of body weight daily in two equal portions at 12-hour intervals 7 days before, and thyroidectomized 5 days before beta carotene supplementation began. Beta carotene was administered to both groups at the rate of 250 I.U. per kilogram of body weight daily in gelatin capsules. Vitamin A and carotene determinations were made and weights taken at 4-day intervals. Average blood plasma vitamin A levels increased from 5.8 to 20.2 and from 10.3 to 24.3 micrograms percent for the control and experimental groups respectively by the fourth day after the beginning of carotene supplementation. After 35 days the blood plasma vitamin A levels were slightly higher in the control group. Carotene was not present in sufficient quantities to be detectable by the Kimble method.

THE NATURE OF REPRODUCTIVE FAILURES IN COWS OF LOW FERTILITY. T. Y. Tanabe and L. E. Casida, *University of Wisconsin.*

The study covered 104 cows, 49 Guernsey and 55 Holstein, each of which had been bred from 4 to 13 times without conceiving. The percentage of genitally-normal cows having fertilized ova when slaughtered at three days was 66.1 but at 34 days the percentage having normal embryos had dropped to 23.1, for an embryonic death rate of 65.1. Estimates were made of

the effect of the following factors on fertilization and embryonic death: (1) breed, (2) Bang's disease, (3) number of previous services, (4) number of previous calvings, (5) herd size and (6) herd breeding index. Appreciable effects upon the fertilization rate were noted for the first and the last three factors, and upon embryonic death rate for the second and the last three. Visible genital abnormalities were found in 10.6 percent of the cows at the time of slaughter; these abnormalities were not detected by clinical examination. There was a higher occurrence in the Holstein (18.2 percent) than in the Guernsey (2.0 percent). The total percentage of cows with genital abnormalities, 10.6, included 8.7 in which the abnormality constituted a physical barrier to fertilization. Considering the group of cows as a whole, including those with genital abnormalities, division may be made into three main categories on the basis of reproductive performance during the first 34 days after breeding: (1) failure of fertilization, 39.7 percent; (2) embryonic abnormalities and mortality before 34 days, 39.2 percent; and (3) embryos still normal at 34 days, 21.1 percent.

THE NATURE OF REPRODUCTIVE FAILURES IN SOWS OF LOW FERTILITY. A. C. Warnick, R. H. Grummer and L. E. Casida, *University of Wisconsin.*

Sixty-three animals that had failed to conceive on 2 to 4 consecutive breedings were obtained from farms throughout Wisconsin and were assembled for detailed study. All animals were mated to fertile boars at the first estrus after being assembled. Animals of group 1 were killed 4 days after breeding to determine the percentage with fertilized eggs, while those of group 2 were retained until 25 days after breeding and the percentage with normal embryos determined. Embryonic death rate was estimated by obtaining the difference between group 1 and 2. Of all animals studied, 39.7 percent had gross bilateral abnormalities. Considering the group of sows as a whole, a division may be made into three main categories on the basis of reproductive performance during the first 25 days after breeding: (1) failure of fertilization, 47.7 percent; (2) Embryonic death before 25 days, 36.4 percent; and (3) normal embryos at 25 days, 15.9 percent. Failure of fertilization (47.7%) may be further subdivided into two classes: (1) accountable 39.7 percent, and (2) unaccountable 8.0 percent. Accountable failure of fertilization included animals with gross genital bilateral abnormalities.

THE INCIDENCE OF FEMALE GENITAL ABNORMALITIES IN SWINE. E. L. Wiggins, L. E. Casida and R. H. Grummer, *University of Wisconsin.*

Twenty-four hundred and forty-nine animals classified as open gilts (group I), open sows (group II), or pregnant sows and gilts (group III) were divided into five weight groups and examined for genital abnormalities. The total percentages of abnormalities were 28, 10 and 7 in groups I, II, and III respectively. Sixteen percent of all animals in group I and 28% of those weighing less than 260 pounds (live weight) had juvenile reproductive organs. Cystic ovaries were found in 1.6%, 2.3% and 1.2% of the animals in the three respective groups with 86% of all cases occurring in animals weighing more than 315 pounds. The incidence of tubal abnormalities was 3.2% in group I compared to 0.8% in group II and 0.6% in group III; thus the data do not support the idea that factors associated with parity increase the incidence of salpingitis, bursitis, etc. Missing portions of the genital tract occurred in 0.8% of the animals in groups I and III and 0.7% of those in group II. Rudimentary ducti deferentia ranging from small fragments of tissue to well developed structures were found in 10% of the open gilts, 6.9% of the open sows and 4.8% of the pregnant animals.

RELATION OF SOURCE OF HORMONE, DOSAGE, AND STAGE OF CYCLE TO SUPEROVULATION IN HEIFERS. E. L. Willett, W. H. McShan and R. K. Meyer, *American Foundation for the Study of Genetics and University of Wisconsin.*

A factorial experiment with twelve heifers was designed to study follicular development and number and fertility of eggs ovulated as affected by: (1) initiation of treatment on the fourth day of the cycle (luteal) versus sixteenth day (follicular), (2) three levels of an extract of follicle

stimulating hormone (FSH) from sheep pituitary glands, namely, 20, 30, and 40 gram-equivalents of desiccated glands, and (3) unfractionated gonadotrophins from sheep pituitary glands versus chorionic gonadotrophin from urine of pregnant women (PU) for the intravenous injection. The treatment consisted of a single subcutaneous injection of FSH each day for five days, intravenous injection on the sixth day, and insemination on the sixth and seventh days. On a statistical basis definite conclusions can not be drawn because of the small number of animals and great variation. The data suggest, however, that more satisfactory results are obtained with the two higher levels of FSH, and that the unfractionated preparation is superior to PU in that twice as many ovulation points were obtained with the former. In light of comparable experiments conducted with the bovine and other species by other workers, the following fairly definite conclusions can be drawn. When an active corpus luteum is present, injection with gonadotrophins and insemination produce pyometra (in all of six cases in this experiment), and the ova are not fertilized. A greater ovarian response is obtained from treatment during follicular than during luteal phase since "follicular" ovaries contained almost twice as many ovulation points.

REPRODUCTIVE ABNORMALITIES OF FEMALES FROM SELECTED AND UNSELECTED POPULATIONS OF SWINE. R. F. Wilson, A. V. Nalbandov and J. L. Krider, *University of Illinois.*

During the 1946 fall breeding season it was found that a high proportion of females from two Hampshire lines bred at the University of Illinois for rapid and slow rates of growth showed breeding abnormalities. Of the 9 sows slaughtered as non-breeders, 8 showed cystic ovaries and 1 showed fibrotic ovaries. During 1947–48 the study was expanded to include females of other breeds from herds of cooperating breeders and the University. Ten gilts and sows from the 2 selected Hampshire lines and 32 females from cooperating breeders (unselected population) were studied. These females had failed to conceive when bred to boars of known fertility in as many as 4 heat periods. Two additional females had never been observed to come in heat. Of the 44 females, 23 (52.3%) conceived when bred during the same heat periods to two project boars of proven fertility. The remaining 21 females which failed to conceive were slaughtered shortly after their last heat. The abnormalities observed included: one missing uterine horn, one or both horns blind, one missing oviduct, hydrosalpinx, individual cystic follicles, cystic ovaries and fibrotic ovaries. Either one or several of these defects were observed in some animals. Reproductive abnormalities were also found in pregnant females. A detailed summary of the incidence of these abnormalities will be presented.

THYROID FUNCTION IN CHICKENS. C. F. Winchester, C. L. Comar and George K. Davis, *Florida Agricultural Experiment Station.*

Thyroids of chicks 2 to 5 days old were completely destroyed by intraperitoneal injections of the order of 6 millicuries of iodine^{131} per 100 grams body weight. After an interval of 8 to 28 days, in 4 series of trials, the smaller of each pair of birds injected with iodine ^{131} at a given level (4, 6 or 8 mc. per 100 gms. body weight) was given daily injections of synthetic thyroxin in water. Thyroxin replacement therapy at levels of the order of 2, 4 and 6 gamma per 100 gms. body weight resulted in resumption of body growth and normal feather development. The iodine^{131} treated birds that did not receive replacement therapy remained greatly retarded in these respects.

NEWS AND NOTES

The Fortieth Annual Meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, Illinois on November 26 and 27, 1948, with a dinner for the Honor Guest on November 28. Abstracts of all submitted papers which are to be presented at the meeting are published in this issue of the JOURNAL OF ANIMAL SCIENCE. Reprints of the Abstract Section of this issue of the JOURNAL will be available to members at the annual meeting.

The Nominating Committee of the American Society of Animal Production, with A. D. Weber as Chairman, has prepared the following slate of officers for consideration by the Society at its annual business meeting in Chicago on November 27:

For President—

W. G. Kammlade
University of Illinois

For Vice President—

P. S. Shearer
Iowa State College

F. L. Bentley
Pennsylvania State College

Members of the Society are reminded of the action taken last year to increase dues and subscription rates beginning January 1, 1949. In accordance with that action, the rate for domestic memberships and subscriptions will be $4.00 per year, and in other parts of North and South America the rate will be $4.50. In all countries outside the Americas, the rate will be $5.00 per year. These changes in rates have been made necessary both because of increased printing costs and increased volume of printing in the JOURNAL OF ANIMAL SCIENCE.

The fourth edition of "Animal Breeding" by Laurence M. Winters, of the Universiy of Minnesota, was published recently by John Wiley & Sons, Inc., New York, N. Y. This volume contains 404 pages and is priced at $4.50. Several chapters of the book have been extended and two new chapters dealing with the effectiveness of selection and the building of superior germ plasm have been added. The organization of the book is indicated by the chapter headings as follows: The Economic Importance of Animal Improvement, Historical Background, The Reproductive Organs, Gametogenesis and the Physical Basis of Heredity, The Breeding Cycle and the Sex Hormones, Fertilization and Prenatal Development, The Role of Heredity, Fundamental Mendelism and Animal Breeding, Lethals, Sex, Selection, The Effectiveness of Selection, Inbreeding, Crossbreeding, Purebred Breeding, Grading, Prepotency, Fertility, Artificial Insemination and Building Superior Germ Plasm. In addition there is a bibliography and a glossary of important terms.

Many readers of the JOURNAL OF ANIMAL SCIENCE are familiar with the publication "Animal Breeding Abstracts" which is issued quarterly by the Commonwealth Bureau of Animal Breeding and Genetics in Edinburgh, Scotland. This journal is now in its 16th volume and is designed to assist workers in all parts of the world who are interested in animal breeding and genetics. The Bureau staff deals with all major foreign languages and is able to obtain access to many lesser known journals. Coverage includes breeds, production, growth, genetics, reproduction and sex and artificial insemination in all forms of livestock, poultry, fur bearers and laboratory animals. In Volume 15 there were 431 abstracts from American journals, which represented 34% of all abstracts in that volume. Mr. J. P. Maule, who was recently named Director of the Bureau, has advised the Editor that the subscription rate is $7.50 (35 shillings) per volume postpaid. Each volume contains four parts, as well as an author index and from Volume 15 there is a subject index. Back Volumes 12–15 are available, as well as some earlier numbers. Subscriptions should be mailed to Commonwealth Agricultural Bureaux, Central Sales Branch, Aberystwyth, Wales, Great Britain.

In a ceremony held in the Jefferson Memorial Auditorium in Washington, D. C. on September 15, various Honor Awards of the U.S.D.A. were awarded to divisions and individuals in the Bureau of Animal Industry. The Tuberculosis Eradication Division received the Distinguished Service Award for its invaluable contribution to the health and welfare of the Nation through organizing, systemizing, and directing the campaign for controlling and eradicating tuberculosis in livestock. The Zoological Division also received the Distinguished Service Award for the discovery and development of phenothiazine, a drug of world-wide application and usefulness for the removal of internal parasites of domestic animals. The Poultry Section of the Animal Hubandry Division received the Superior Service Award for achievement in practical poultry research. Length of Service Awards were given to several staff members who are members of the American Society of Animal Production, including Ralph G. Schott, who received a 10-Year Award; A. C. Cook, who received a 20-Year Award; and O. G. Hankins, D. A. Spencer and J. H. Zeller, who received 30-Year Awards.

Fred S. Hultz, formerly head of the animal husbandry department, University of Wyoming, has resigned to become president of North Dakota Agricultural College. Dr. Hultz will replace J. H. Longwell who resigned to become Dean and Director, College of Agriculture and Agricultural Experiment Station at the University of Missouri.

Paul Swaffer, formerly field representative for the American Hereford Association, has joined the animal husbandry extension staff at the North Carolina State College. Prior to his work with the American Hereford Association, Mr. Swaffer was on the staff at the Virginia Polytechnic Institute.

W. W. Green returned to the University of Minnesota on August 1 after serving for one year as head of the animal husbandry department of the Agricultural Experiment Station at the University of Puerto Rico in Rio Piedras. Dr. Green assumed a new post as Professor of Animal Husbandry at the University of Maryland on September 1, where he is in charge of he animal breeding work.

Tony J. Cunha, of the animal husbandry department of the State College of Washington, has resigned and has accepted a post at the University of Florida, effective September 1. He will do research and teaching in animal nutrition in the animal husbandry department at the University of Florida.

A book entitled "Pregnancy Diagnosis—A Review," was issued in September 1948 by the Commonwealth Agricultural Bureaux as Joint Publication No. 13. It represents the joint efforts of the Commonwealth Bureaux of Animal Breeding, Dairy Science, and Animal Health, and was prepared by Alfred T. Cowie of the National Institute for Research in Dairying. The author has surveyed all the important papers on the diagnosis of pregnancy in domestic animals and in women, with the exception of those concerned with clinical methods in women. The opening chapter deals with clinical methods applied to domestic animals, and other tests are classified according to their basis on hormonal, enzymic, other biological, immunological and physiological phenomena. The techniques and the accuracy of the different methods under varying conditions and for different species is assessed. An exhaustive bibliography is included, and the volume is indexed by tests and by animals. It will be of direct interest to all research workers in fields of animal and human reproduction, and to all animal physiologists, veterinarians, physicians and others who may be interested in the application of pregnancy tests. The volume contains 283 pages, is priced at 15 shillings, and may be obtained from the Central Sales Branch, Commonwealth Agricultural Bureaux, Penglais, Aberystwyth, Wales, Great Britain.

J. W. Howe, formerly of the University of Alberta, is now Director of the Division of Agriculture at the Texas College of Arts and Industries, Kingsville, Texas.

The twenty-first edition of "Feeds and Feeding" by F. B. Morrison was published in October 1948 by The Morrison Publishing Company of Ithaca, New York. This is not only the twenty-first edition of this well-known textbook but it appeared on the fiftieth anni-

versary of the first edition which was prepared by William Arnon Henry. In preparing the twenty-first edition the author has compiled and analyzed the results of many recent experiments on livestock feeding and nutrition conducted in the United States and other countries and this information has been added to that contained in earlier editions. The volume is intended to present in as simple and concise a manner as is possible the most important factors concerning the nutrition, feed, care and management of the various classes of farm animals and to give full information concerning the composition, use and value of all important feeding stuffs. The new edition has been entirely rewritten, includes extensive new compilations of feed analyses in the appendix tables, contains 1207 pages and over 200 illustrations, and is bound in a high-grade fabricoid. It is priced at $7.00, and is sent prepaid when cash accompanies the order. This new edition should serve even more fully than past editions as an important part of every animal husbandman's library.

D. E. Brady, Professor of Animal Husbandry at North Carolina State College of Agriculture, resigned to accept a position at University of Missouri, September 1, 1948.

Paul Q. Guyer has accepted a position in the Animal Husbandry Department, University of Missouri, as an assistant instructor.

Louisa Nelson Tucker, formerly Laboratory Technician at North Carolina State College of Agriculture, has accepted a position as assistant instructor in Animal Husbandry, University of Missouri, effective November 1, 1948.

A conference on statistics applied to research in the social sciences, plant sciences, and animal sciences was held at Auburn, Alabama, September 7–9 inclusive. There were 92 applied scientists and statisticians registered and in attendance from 14 states and Washington, D. C. The Conference was sponsored by Alabama Polytechnic Institute in cooperation with Iowa State College, University of North Carolina, Virginia Polytechnic Institute, United States Department of Agriculture, and Southeastern Agricultural Experiment Stations. Lectures were given on techniques and designs involved in the application of statistical technique to research problems in the above mentioned sciences. The lectures were followed by brief research reports illustrating the use of the statistical techniques in actual experimental situations. The lectures in full accompanied by abstracts of the brief research reports will be made available in the near future by the Statistical Laboratory, Alabama Polytechnic Institute, Auburn, Alabama.

Elmer H. Hughes has been made chief of the animal husbandry division, University of California, succeeding George H. Hart, who became dean of the new school of veterinary medicines at the same institution.

Alvin H. Sanders, long associated with the Breeders Gazette and author of several livestock books, died on July 18 at Wayne, Pennsylvania, at the age of 87.

John M. Evvard, eminent animal scientist and author with periods of service with the State experiment stations of Iowa and Missouri, recently died at the age of 63 at Phoenix, Arizona.

The Remount Service of the Department of the Army was transferred to the Department of Agriculture, effective July 1, 1948, by act of the 80th Congress. The Agriculture Remount Service is an independent unit of the Agricultural Research Administration with Colonel R. E. Ireland temporarily in immediate charge.

Harry Vollrath, of the Hawaiian Extension Service, has returned to duty as leader of the animal husbandry project, University of Hawaii, after a year's graduate study at the University of Minnesota.

George R. Carlisle was appointed extension animal husbandman, effective July 1 at the University of Illinois, to succeed Raymond D. French who resigned.

Murray D. Trump was appointed extension wool specialist, effective July 1, at the University of Wyoming.

Harry P. Gayden, animal husbandry extension specialist at Louisiana State University, has been granted leave of absence for one year to act as secretary of the American Brahman Breeders' Assn. with headquarters at Houston, Texas.

Robert D. Rasmussen was appointed associate animal husbandman with the New Mexico Extension Service effective August 1, to succeed Joe V. Whitman, who is now in charge of field work in wool marketing and ram certification in cooperation with R&MA.

W. A. Ridgeway, who was appointed extension animal husbandman in the South Carolina Extension Service last year, has returned to county agent work in the same State.

Virgil V. Parr, an animal husbandry graduate of the Texas A & M College and formerly associated with the Bureau of Animal Industry, and Soil Conservation Service, USDA, died at his home, Bryan, Texas, after a long illness on September 13, 1948.

James B. Outhouse of the Animal Husbandry Department at the University of Maryland, is now on leave while taking graduate work at Purdue University.

John W. Schwab, long-time swine specialist with the Purdue University Extension Service, retired June 30, 1948, and was succeeded by E. C. Miller, formerly county agent in Clinton County, Indiana.

Chester W. Rubel, former district agent California Extension Service, is now acting Director of Extension at Berkeley, following the decease of B. H. Crocheron.

Raymond F. Pifer, former member of the animal husbandry staff, University of Kentucky, and more recently with a commercial firm in St. Louis, Missouri, has been appointed professor of animal husbandry, Ohio State University, effective October 1, 1948.

Clarence Beaman Smith, pioneer extension administrator with the U. S. Department of Agriculture and one time editor of the Experiment Station Record died at his home in Washington, D. C. in September at the age of 78.

Berry N. Duff has returned to his position of sheep and wool specialist in the Colorado Extension Service, after serving for a period as Secretary of the Colorado Wool Growers Assn.

R. C. Tom, formerly head of the animal husbandry department at Colorado State College, has joined the research staff of Swift & Co. in Chicago.

J. C. Pierce, Jr., of the animal husbandry department, North Carolina State College, resigned recently to accept a position with the livestock branch, Production and Marketing Administration, USDA, Washington, D. C.

SUBJECT INDEX FOR VOLUME 7

A

Acids—
amino, requirements of, in swine, 530
content of, in meat and meat products, 533
lysine, 530
requirements of, in ruminants, 534
purified diets for study of, 534
ascorbic, in vitamin-A deficient beef bulls, 60
chlorobutanol, effect of, on plasma ascorbic acid levels in sheep, 191
cholesterilene sulfonic, in treatment of mammalian rickets, 534
cystine, as supplement to soybeans for pigs, 341
fatty, effect of, on blood ketone levels of ruminants, 544
niacin levels in blood of swine, 222
nicotinic acid, in blood of swine, 222
for growing pigs, 228
relation of tryptophane to, 228
pantothenic, in studies with horses, 78
deficiency in natural feedstuff diets of swine, 529
tryptophane, relation of, to nicotinic acid for growing pigs, 228

Age—
weaning weight of calves as related to age of dam, 514

Alfalfa—
and soil, as unidentified factor in young pig's appetite, 523
ash, influence on roughage digestion in cattle, 522
meal, dehydrated, in drylot weanling pig rations, 535
hay, ground, added to prairie hay for dairy cow rations, 537
meal, dehydrated, in drylot weanling pig rations, 535
mixed with bromegrass, methods of management, 99
water extract of, effect on roughage digestion in cattle, 522

American Feed Manufacturers Association—
awards for dairy cattle, livestock and poultry nutrition, 257
rules governing, 257

American Society of Animal Production—
Honor Guest for 1947, 149
index of committee chairmen for 1948, 147
index of program chairmen for 1948, 147
index of special representatives for 1948, 147
minutes of 39th Business meeting, summary of, 137
Morrison Award for 1947, 151
proceedings of 39th Annual Meeting, 135

Anemia, pernicious—
liver extract, as growth stimulant in baby pigs, 528
new factors in, 528

Artificial insemination—
freezing point depression of bull semen, 283
relation to diluters, 283
semen diluted with citrate, 541
diluted with ortho, 541
diluted with phosphate, 541
results in inseminated dairy cows, 541

Ascorbic acid—
failure of, to increase semen quality of vitamin-A deficient beef bulls, 60
to increase sexual activity of vitamin-A deficient beef bulls, 60

Ayrshire cattle—
heritability of body size of, 516

B

Bacteria—
in rumen of cattle, on summer rations, 525
on winter rations, 525
in rumen of sheep, on summer rations, 525
in cobalt-deficient sheep, 526
on winter rations, 525

Biotin—
in treatment of experimentally induced paralysis in calves, 525
versus potassium, 525

Blood—
calves', 70, 532, 538
carotene, effect of thiouracil on, in dairy calves' blood, 538
carotenoids, 70
content of, in blood of newborn calf, 525
effect of pasture ration on, 525
postnatal dietary changes, and blood of, 70
cholrobutanol, for sheep, 191
effect of, on plasma ascorbic acid levels, 191
diet, postnatal, 70
relation of changes in, to carotenoids

in blood of, 70
to vitamin A in blood of, 70
effect of ration on, 532
Haemonchus contortus, in lambs, 520
effect on B-vitamins in blood of, 520
Hereford cows, effect of ration, on blood of, 532
ketone levels of ruminants, 544
fatty acids, effect of, on, 544
phosphorus levels of, in range cattle, 263
effect of ration, on milk of, 532
on milk of calves, 532
plasma ascorbic acid levels in sheep, 191
vitamin A, 70
postnatal dietary changes, and blood of, 70
composition, in identical cattle twins, 511
hemopoietic dietary factors, effect on parasitism in lambs, 466
Haemonchus contortus, 466
niacin level in blood of swine, 222
nicotinic acid level in blood of swine, 222
plasma vitamin C levels in newborn lambs, 527
administration of vitamin C, effect on, 527
serum proteins, of pregnant ewes, 529
amount of protein, effect of, on, 529
kind of protein, effect of, on, 529
of offspring, 529
amount of protein, effect of, on, 529
kind of protein, effect of, on, 529
thiouracil, effect of, on carotene in dairy calves' blood, 538
thyroprotein, effect of, on carotene in dairy calves' blood, 538
vitamin A, level in blood of swine, 222
vitamin A, effect of thiouracil on, in dairy calves' blood, 538
of thyroprotein on, in dairy calves' blood, 538
vitamin C, level in blood of swine, 222
vitamin C, for newborn lambs, 527
effect on blood plasma vitamin C levels, 527
Bonemeal—
as phosphorus supplement for fattening steers, 273
Breeding—
abnormalities, of female genitalia in swine, 545
incidence, 545
of reproduction in sow, 540
histology, of, 540
incidence, 540
ascorbic acid, in vitamin-A deficient beef bulls, 60
failure of, to improve semen quality, 60
to increase sexual activity, 60
bacon-type hog, production of, 511
feed and climatic conditions of Pacific Northwest, 511
blood serum proteins, of pregnant ewes, 529
amount of protein, effect on, 529
kind of protein, effect on, 529
of offspring, 529
amount of protein, effect of, on, 529
kind of protein, effect of, on, 529
carotene, in vitamin-A deficient beef bulls, 60
effect of, on semen quality, 60
on sexual activity, 60
corn-soybean oil meal rations for swine, reproduction studies of, 528
corpora lutea ablation in goats, 542
progesterone as replacement therapy, 542
Corriedale×Navajo, comparison with Romney×Navajo crosses, 455
cows, low fertility in, failure to reproduce, 545
dried fermentation solubles for sows during gestation, 332
estrogen combined with thyroprotein for feeding, 541
effect on milk production, 541
estrus, cycle of cow, 540
progesterone, effect of, in altering, 540
estrus cycle in heifers, 545
relation of state of, to superovulation, 545
experimental, of animals adapted to climatic stress, 417
fertility of dairy bulls, 514
effect of season on, under Michigan conditions, 514
gonads, response to pregnant mares' serum, 542
effect of thyroid status on, 542
heifers, superovulation in, 545
estrus cycle, relation to, 545
hormone, dosage of, relation to, 545
source of, relation to, 545
heritability of body size of Ayrshire cattle, 516
heterosis, study of, in swine, 515
hothouse lamb production, 513
birth weights of, 513
daily gains in, 513

lactation studies of swine fed corn-soybean oil meal rations, 528
mares' serum, pregnant, response of gonads to, 542
effect of thyroid status on, 542
Navajo×Corriedale, comparison with Navajo×Romney, 455
Navajo ewes, 515
size of weaning lambs as permanent characteristic of, 515
progesterone, effect of, in altering estrus cycle of cow, 540
use of, in goats, 542
as replacement therapy of corpora lutea ablation, 542
pteroylglutamic acid deficiency in newborn pigs, 486
synthetic diet, use of, to produce, 486
ram semen, effect of thyroprotein on, 191, 199, 449
rats fed natural and purified rations, 531
effect of supplements on reproduction performance, 531
reactions of Southdown sheep to two environments, 41
reproduction abnormalities in sow, 540
reproduction studies of swine fed corn-soybean oil meal rations, 528
reproductive abnormalities of female swine, 545
reproductive failures, in cows of low fertility, 544
in sows of low fertility, 545
Romney×Navajo, comparison with Corriedale×Navajo crosses, 455
semen quality of vitamin-A deficient beef bulls, 60
ascorbic acid, failure of, to improve, 60
carotene, effect of, on improvement of, 60
chlorobutanol, effect of, on semen production in sheep, 191
sexual activity of vitamin-A deficient beef bulls, 60
ascorbic acid, failure of, to improve, 60
carotene, effect of, on improvement of, 60
soybean lecithin, effect on vitamin A fed prepartum to ewe and sow, 524
soybean oil meal-corn rations for swine, reproduction studies of, 528
sows, bred, efficiency of, at slaughter, 92
low fertility in, failure to reproduce, 545
open, efficiency of, at slaughter, 92
spermatogenesis of dairy bulls, 514
effect of season on, under Michigan conditions, 514
superovulation in heifers, 545
relation, of dosage of hormone to, 545
of source of, to 545
of stage of cycle to, 545
synthetic diet for newborn pigs, 486
steroylglutamic acid deficiency, 486
testicular development of swine, 512
thyroprotein, effect of, on ram semen, 191, 199, 449
twins, identical cattle, similarities of, 511
blood composition, 511
growth, 511
vertebrae number in pig, genetical researches on, 233
weaning size of lambs, as permanent characteristic of Navajo ewes, 515
Bromegrass—
mixed with alfalfa, methods of management, 99

C

Carbohydrate—
dehydrated sweet potatoes for fattening swine, 533
Carcass, swine—
composition of thiouracil-fed swine, 533
quality of, 531
effect of thyroprotein on, 531
Carcinoma—
ocular epithelioma in Hereford cattle, 426
relation of eyelid pigmentation to, 426
Carotene, effect of, on semen quality in vitamin-A deficient beef bulls, 60
absorption of, from gastrointestinal tract of sheep, 539
effect of, on sexual activity of, in vitamin-A deficient beef bulls, 60
effect of thiouracil on carotene, in dairy calves' blood, 538
of thyroprotein on, 538
metabolism in goats, 544
effect of thyroidectomy plus thiouracil feeding on, 544
Carotenoids—
content of, in blood of newborn calf, 525
effect of pasture ration on, 525
in blood of dairy calves, 70
relation of postnatal dietary changes to, 70
Casein, iodized—
influence of, on metabolism of milk cows, 291

Cattle—
amino acid requirements of, 534
purified diet for study of, 534
Ayrshire, heritability of body size of, 516
bacteria in rumen of cattle, on summer rations, 525
on winter rations, 525
blood ketone levels of ruminants, 544
effect of fatty acids on, 544
blood phosphorus levels of range cattle in Southwest, 263
bonemeal as phorphorus supplement for fattening steers, 273
bull semen, freezing point depression of, 283
development of hyaluronidase in, 440
as factor of fertility, 440
association with spermatozoa, 440
effect of toluene on, 444
bull spermatozoa, preservation of, 447
carotenoid content of blood of newborn calf, 525
effect of pasture ration on, 525
deflorinated superphosphate for fattening steers, 273
epithelioma, ocular, in Herefords, 426
estrus cycle, of cow, 540
progesterone, effects of, on altering, 540
stage of cycle, relation of, to superovulation in heifers, 545
eyelid pigmentation in Herefords, 426
relation to ocular epithelioma, 426
greenlot fattened steers, 537
effects of concentrate supplements on, 537
heritability of body size of Ayrshires, 516
of Holstein-Friesian, 516
Holstein-Friesian, heritability of body size of, 516
hormone, dosage of, relation to superovulation in heifers, 545
source of, relation to, 545
Michigan's cow and feeder calf program, 536
for utilization of pasture, 536
of roughage, 536
paralysis in calves, experimentally induced, 525
biotin in treatment of, 525
versus potassium, 525
pasture ration, effect on vitamin A, in blood of newborn calf, 525
on carotenoid content of, 525
prairie hay, digestibility of, by steers, 110
reproductive failures in cows of low fertility, 544
roughage digestion in, 522
alfalfa ash, effect of, on, 522
water extract of alfalfa, effect of, on, 522
steer calves, effect of winter rations on summer gains, 536
superovulation in heifers, 545
dosage of hormone, relation of, to, 545
source of hormone, relation of, to, 545
stage of cycle, relation of, to, 545
thiouracil, absorption of, in, 208
elimination of, in, 208
twins, identical, similarities of, 511
blood composition, 511
differentiation between fraternal and, 516
growth, 511
vitamin A in blood of newborn calf, 525
effect of pasture ration on, 525
weights, initial and subsequent, of weanling calves, 279
related to age of dam, 514
to color, 514
to sex, 514
Cattle, beef—
ascorbic acid, in vitamin-A deficient beef bulls, 60
failure of, to increase sexual activity of, 60
to improve semen quality of, 60
carotene, in vitamin-A deficient beef bulls, 60
effect of, on sexual activity, 60
on semen quality, 60
lupine seed, for growing and fattening steers, 526
value as protein supplement for, 526
semen of vitamin-A deficient beef bulls, 60
ascorbic acid, failure of, to improve quality of, 60
carotene, effect of, to increase quality of, 60
sexual activity of vitamin-A deficient beef bulls, 60
ascorbic acid, failure of, to increase, 60
carotene, effect of, to increase, 60
stilbestrol, effect on growth and fattening of heifers, 523
testosterone, effect on growth and fattening of heifers, 523
thyroid, effect on growth and fattening of heifers, 523

vitamin A deficient beef bulls, 60
ascorbic acid, failure of, to increase semen quality of, 60
to increase sexual activity, 60
carotene, effect of, to increase semen quality of, 60
to increase sexual activity of, 60
winter rationing for steers, 430
protein supplement, effect of, gains of calves, 430
Cattle, dairy—
alfalfa hay, as supplement to prairie hay for rations of, 537
artificial insemination of dairy cows, 541
blood of calves, 70, 532, 538
carotene, effect of thiouracil on, in calves, 538
of thyroprotein on, 538
carotenoids in, 70
relation of postnatal dietary changes to, 70
effect of ration on, 532
vitamin A in, 70
relation of postnatal dietary changes to, 70
body size, influence of, on reaction to high ambient temperatures, 539
bulls, effect of season upon fertility of, in Michigan, 514
upon spermatogenesis of, 514
carotene, effect of thiouracil on, in blood of calves, 538
of thyroprotein on, 538
carotenoids in blood of calves, 70
relation of postnatal dietary changes to, 70
clipping of, physiological effects, 543
cobalt toxicity in dairy calves, 239
cooling of, 251
sprinkling device for, 251
diet, postnatal changes in, of calves, 70
relation of, to carotenoids in blood of calves, 70
diluters of semen, for dairy cows, 541
citrate, 541
ortho, 541
phosphate, 541
distillers feeds, use of, in calves' rations, 434
as source of proteins, 434
of vitamins, 434
estrogen and thyroprotein, effect of combined feeding on milk production, 541
fat percentage, regression of milk energy on, 55
Hereford cows, effect of ration on blood of, 532
on blood of calves, 532
on milk of, 532
iodized casein, effect of, on metabolism of milk cows, 291
milk energy, regression of, on fat percentage, 55
protein content of distillers feeds, for calves' rations, 434
reaction of, to high ambient temperatures, 539
influence of body size on, 539
temperatures, high ambient, reaction of dairy cattle to, 539
influence of body size on, 539
thyroprotein, and estrogen, effect of combined feeding on milk production 541
effects of, in dairy calves' rations, 542
vitamin A, in blood of calves, 70, 538
effect of thiouracil on, in dairy calves' blood, 538
of thyroprotein on, 538
relation of postnatal dietary changes to, 70
vitamin B-complex, in calves' rations, 434
Chlorobutanol—
effect of, on plasma ascorbic acid levels in sheep, 191
Cholesterilene sulfonic acid—
new vitamin D, in treatment of mammalian rickets, 534
in chickens, 534
in rats, 534
Choline—
requirement of baby pig, 530
supplement to corn-soybean ration, 502
Citrate diluter—
results of, in inseminated dairy cows, 541
Climate—
adaptability of livestock to climatic stress, 391
assessment of, 391
effect of season, upon fertility of dairy bulls in Michigan, 514
upon spermatogensis of, 514
of Pacific Northwest, suitability of, in producing bacon-type hog, 511
Clipping—
of dairy cows, physiological effects, 543
Cobalt—
deficiency in sheep, 526
in New Hampshire, 16
rumen bacteria in, 526

effect of, in sheep rations, 523
in sheep nutrition, 3
oral administration, in calves, 239
toxicity, in calves, 239
Color—
calves, relation of weaning weight to, 514
Columbia rams—
effects of environmental factors on yearling traits of, 181
Corn—
by-products in swine rations, 527
manganese supplementation, effect of, on growth of swine, 527
rations, for swine, 527
manganese supplementation, effect of, on growth, 527
Corn-soybean—
in ration for weanling pigs, 502, 524
oil meal rations, for swine, 528
lactation studies of, 528
reproduction studies of, 528
Corpora lutea ablation—
in goats, 542
progesterone as replacement therapy, 542
Corriedale×Navajo, comparison with Romney×Navajo crosses, 455
Cottonseed meal—
as supplement to prairie hay for steers, 112
solvent extracted, as protein concentrate for pigs in drylot, 531
Cull peas—
as protein supplement for swine feeding, 117
Cystine—
as supplement to soybeans for pigs, 341

D

DDT—
accumulation of, in pigs fed beef containing DDT, 509
Diet—
alfalfa and soil, factor in young pig's appetite, 523
alfalfa hay, ground, with prairie hay in dairy cow rations, 537
alfalfa meal, dehydrated, in drylot weanling pig rations, 535
ascorbic acid, in vitamin-A deficient beef bulls, 60
failure to improve semen quality in, 60
to increase sexual activity in, 60
bacteria in rumen of cattle and sheep, on summer rations, 525
on winter rations, 525
B-vitamin supplements to corn-soybean ration, 502
blood of Hereford cows and calves, 532
effect of ration on, 532
blood phosphorus levels in range cattle, 263
bonemeal, as phosphorus supplements for fattening steers, 273
carotene, in vitamin-A deficient beef bulls, 60
effect of, on improving semen quality in, 60
on increasing sexual activity in, 60
carotenoids in blood of dairy calves, 70
cobalt, deficiency in sheep, in New Hampshire, 16
effect of, in sheep rations, 523
function of, in sheep, 3
toxicity in calves, when administered orally, 239
corn-soybean, ration for weanling pigs, 502
B-vitamin supplements to, 502
oil meal rations for swine, 522
lactation studies, 528
reproduction studies, 528
concentrate supplements for steers, 537
cottonseed meal as supplement to prairie hay for steers, 112
cull peas as protein supplement for swine feeding, 117
cystine, as supplement to soybeans for pigs, 341
dietary fat, effect of, on utilization of rations by sheep, 475
distillers feeds in dairy calves' rations, 434
dried fermentation solubles for sows, 332
dry matter intake, relation to fecal nitrogen excretion, in steers, 110
effect of ration on composition of sow's milk, 521
feed conditions of Pacific N.W. for producing bacon-type hog, 511
fish solubles, in drylot weanling pig rations, 535
forages, nutrient value of, 373
under range conditions, in sheep's diet, 170
grains of different protein content, feeding of, 494
haemopoietic dietary factors, effect of, on parasitism in lambs, 466
horses, pantothenic acid studies with, 78
meat scraps, in drylot weanling pig rations, 535

milk of Hereford cows and calves, 532
effect of ration on, 532
niacin, in blood of swine, 222
nicotinic acid, for growing pigs, 228
nutrient value of forages, 373
pantothenic acid, studies with horses, 78
deficiency in natural feedstuff diets of swine, 529
pasture, value of, as supplement for feeding young pigs, 538
phosphorus levels of blood of range cattle, 263
postnatal changes in dairy calves, 70
relation to carotenoids in dairy calves' blood, 70
to vitamin A in dairy calves' blood, 70
prairie hay, digestibility of, by steers, 110
supplemented by ground alfalfa hay in dairy cow rations, 537
protein, fed to pregnant ewes, 529
amount of, effect on blood serum proteins of ewes, 529
effect on offspring, 529
kind of, effect on blood serum proteins of ewes, 529
effect on offspring, 529
protein content of distillers feeds, for dairy calves' rations, 434
of grains, variation of, 494
protein supplement to winter rations for beef steers, 430
pteroylglutamic acid deficiency in newborn pigs, 486
synthetic diet, effect on producing, 486
purified diets for study of amino acid requirements of ruminants, 534
range foraging, for sheep, 170
nutrient value of forages, 373
rats fed natural and purified rations, 531
effect of supplements to, on lactation performance of, 531
on reproduction performance of, 531
soybeans, supplemented by cystine, for pigs, 341
by B-complex, 341
soybean-corn ration for weanling pigs, 502, 524
supplemented, by B-vitamins, 502
by known factors, 524
by unknown factors, 524
supplementary feeding of individual sheep on winter range, 529
sweet potatoes, dehydrated, for fattening swine, 533
steers, digestibility of prairie hay by, 110
relation of fecal nitrogen excretion in relation to dry matter intake, 110
winter rations, effect of, on summer gains of steer calves, 536
synthetic diet for newborn pigs, 486
pteroylglutamic acid deficiency, 486
thiouracil, effect of, on rations of swine, 84, 214, 527
fed to swine, 533
carcass composition, 533
nitrogen balances, 533
on efficiency of gains in swine, 534
on rate of gains in swine, 534
when given in addition to thyroprotein, 84
thyroprotein, effect of, on rations of swine, 84, 527
effect of, in feeding to dairy calves, 543
effect of, on growth and fattening of swine, 531
when given in addition to thiouracil, 84
tryptophane for growing pigs, 228
relationship of, to nicotinic acid, 228
urea, utilization of, by sheep, 26
as extender of protein in lambs, 35
vitamin A in blood of dairy calves, 70
vitamin B-complex in dairy calves' rations, 434
vitamin B, in diet of horses, 78
vitamin E, deficient ration for boars, 528
effect on fertility, 528
vitamin supplement for sows fed in drylot, 332
vitamins, value of, in young pig's diet, 523
whey, dried, in drylot weanling pig rations, 535
fermentation solubles in, 535
winter rations for steer calves, 430, 536
effect of, on summer gains, 536
protein supplement, effect on gains, 430
Digestibility—
alfalfa ash, effect on roughage digestion in cattle, 522
water extract of, effect on roughage digestion in cattle, 522
balance trials with "compact" Shorthorn steers, 129
with conventional type Shorthorn steers, 129
data, variability in, 532
magnitude of sources of, 532

of forages, 373
of prairie hay, by steers, 110
cottonseed meal as supplement to hay, 110
dry matter intake, relation of fecal nitrogen excretion, 110
excretion, fecal nitrogen of, 110
relation to dry matter intake, 110
fecal nitrogen excretion of, 110
relation to dry matter intake, 110
nitrogen excretion experiments with, 110
relation to dry matter intake, 110
nutrient utilization by "compact" Shorthorn steers, 127
by conventional type Shorthorn steers, 127
of pasture forages, 536
protein requirements of ruminants, 351
metabolic fecal nitrogen, 351
protein wastage, 110
supplement of cotton seed meal, 112
roughage digestion in, 522
alfalfa ash, effect of, on, 522
water extract of alfalfa, effect of, on, 522
Distillers dried feeds—
fed to pigs in drylot, 531
in rations of dairy calves, 434

E

Environmental factors—
effects of, on yearling traits of Columbia rams, 181
on mature Rambouillet rams, 311
on yearling Rambouillet rams, 311
on yearling Targhee rams, 181
on weaning weights of lambs, 515
age of dam, 515
age of lambs at weaning, 515
as permanent characteristic of Navajo ewes, 515
breed of sire, 515
sex, 515
type of birth and rearing, 515
year of birth, 515
Epithelioma, ocular—
in Hereford cattle, 426
relation of eyelid pigmentation, 426
Eyelid pigmentation—
in Hereford cattle, 426
relation of, to ocular epithelioma, 426

F

Fat—
in diet of sheep, effect on energy and protein of rations, 475
milk energy, regression of, on fat percentage, 55
Feeding trials—
for swine, 320
grains of different protein content, 494
Fertility—
low fertility in cows, 544
reproductive failures, 544
low fertility in sows, 545
reproductive failures, 545
of boars, 528
when fed vitamin E deficient ration, 528
of dairy bulls, effect of season on, 514
soil, relation to animal production, 159
to plant production, 159
Fish solubles—
in drylot weanling pig rations, 535
Forage—
chemical composition of pasture, 536
relationship of, to digestibility of pasture, 536
to palatability of, 536
digestibility of, 536
relationship of, to composition of, 536
to palatability of, 536
grass tetany, in ewes grazing winter oats, 535
nutritive content of range, 373
in sheep's diet, 170
palatability of, 536
relationship to composition of, 536
to digestibility of, 536

G

Goats—
carotene metabolism in, 544
thioracil feeding plus thyroidectomy effect on, 544
progesterone in gestation of, 542
as replacement therapy for corpora lutea ablation, 542
thiouracil feeding plus thyroidectomy to 544
effect on carotene metabolism in, 544
thyroidectomy plus thiouracil feeding, 544
Grains—
of different protein content, feeding of, 494
Grass tetany
in ewes grazing winter oats, 535

H

Haemonchus contortus, in lambs, 466
effect of hemopoietic dietary factors on resistance to, 466

infection, effect on B-complex vitamins in blood of, 520
effect on rumen of lambs, 520
Hams, Southern style—
sugar, as production factor, 517
Hay—
prairie, digestibility of, by steers, 110
alfalfa hay supplement to, in dairy cow rations, 537
cottonseed meal as supplement to, 112
Hogs—see swine
Holstein-Friesian cattle—
heritability of body size of, 516
Hormones—
pregnant mares' serum, response of gonads to, 542
effect of thyroid status on, 542
progesterone, effects of, in altering estrus cycle of cow, 540
as replacement therapy of corpora lutea ablation, 542
in gestation in goats, 542
source of, relation to superovulation in heifers, 545
Horses—
diet, deficiency B-vitamines in, 78
pregnant mares' serum, response of gonads to, 542
effect of thyroid status on, 542
pantothenic acid in diet of, 78
Hyaluronidase—
development of, in bull semen, 440

I

Inbreeding—
comparisons of inbred Poland China, Landrace and purebred boars, 512
differences in testicular development of swine on Iowa farms, 512
heterosis, study of, in swine, 515
selection, in inbred lines of swine, 513
effectiveness of, for quantitative character, 514
sex ratios among inbred, noninbred and linecross pigs, 516
Iodine—
deficiency in newborn sheep, 298
in newborn swine, 298
Iodized casein—
influence of, on metabolism of dairy cows, 291

K

Ketone levels of ruminants—
fatty acids, effect of, on, 544

L

Lactation—
dried fermentation solubles for sows during, 332
performance of rats, 531
effect of supplements to natural and purified rations on, 531
studies of swine fed corn-soybean oil meal rations, 528
Lams—see sheep
Landrace boars—
inbred with Poland China and purebred, 512
Liver—
choline requirement of baby pigs, 530
Liver extract—
antipernicious anemia, to stimulate growth in baby pigs, 528
new factors in, effect on, 528
Livestock—
adaptability to climatic stress, 391
activity of animals, 407
assessment of, 391
barometric pressure, 396
characteristics of animals, 418
effect of food deficiency, 406
of water deficiency, 406
endocrine response, 401
experimental breeding, 417
heat balance, 393
mechanical effects, 407
methods of studying reactions of animals, 409
parasites and infections, 407
sunburn, 407
thermal elements, 396
compensatory reactions to, 397
secondary reactions to, 397
parasite problems of, 517
Lupine seed—
for fattening and growing beef steers, 526
as protein supplement for, 526
Lysine—
requirements of swine, 530

M

Manganese—
as supplement, to corn rations for swine, 527
effect of, on growth of swine, 527
to corn by-products for swine rations, 527
Measurements—
of body, in swine, 513
relationship of, to yield of 5 preferred cuts, 513

Meat—
amino acid content of, 533
frozen storage meat, factors influencing quality of, 519
methods of protection in freezer storage, 519
relation of quality of meat to, 519
mold control in stored cured pork, 518
nonrefrigeration for curing pork under farm conditions, 518
scraps, in drylot weanling pig rations, 535
short loins, shear tenderness tests, 517
storage of beef and pork, 518
ultraviolet irradiation for low temperature, 518
tenderness of beef at different intervals after slaughter, 519
effect of methods of cooking on, 519
initial chemical changes, relation to, 519
initial physical changes, relation to, 519
Memorials—
Benton, E. L., 145
Boss, A., 145
Curtiss, C. F., 145
Humphrey, G. C., 145
Richardson, L. A., 145
Metabolic rate—
of rats, effect of thiouracil on, 521
Michigan—
cow and feeder calf program, 536
for utilization of pasture, 536
of roughage, 536
Milk—
production, 541
effect of combined estrogen and thyroprotein feeding on, 541
of Hereford cows and their calves, 532
effect of ration on, 532
Milk energy—
composition of sow's milk, effect of lactation on, 521
effect of ration on, 521
regression of, on fat percentage, 55
Mold control—
in stored cured pork, 518
Morrison Award for 1947, 151

N

Navajo×Corriedale crosses, 455
comparison with Romney×Navajo crosses, 455
Navajo ewes—
size of lambs at weaning as permanent characteristic of, 515
New Hampshire—
cobalt deficiency in, with sheep, 16
News and Notes, 152, 257, 383, 547
Niacin, levels in blood of swine, 222
in growing pigs, 228
relationship of tryptophane to, 228
supplementary to corn-soybean ration, 502
Nicotinic acid, in blood of swine, 222
in growing pigs, 228
relationship of tryptophane to, 228
Nitrogen—
balance experiments with steers, 110
balances of swine fed thiouracil, 533
cottonseed as supplement to prairie hay for steers, 112
metabolic fecal nitrogen in ruminants, 351
of urea, utilization of, by sheep, 26
Nutrition—
analysis of carcass cuts following slaughter of steers, 128
summary of feed-lot data, 133
of slaughter date, 133
ascorbic acid, in vitamin-A deficient beef bulls, 60
failure of, on improving semen quality in, 60
increasing sexual activity of, 60
carotene, in vitamin-A deficient beef bulls, 60
effect of, on improving semen quality in, 60
increasing sexual activity of, 60
cobalt, in sheep, 3
deficiency of, in N.H., with sheep, 16
cystine, as supplement to soybeans for pigs, 341
dried fermentation solubles for sows, 332
in range foraging sheep's diet, 170
iodine deficiency in newborn sheep, 298
in newborn swine, 298
niacin, in blood of swine, 222
nicotinic acid, in blood of swine, 222
for growing pigs, 228
nutrient utilization by compact Shorthorn steers, 127
by conventional type Shorthorn steers, 127
soybeans in pig rations, 341
supplemented by cystine, 341
by B-complex, 341
thiouracil, effect of, on swine, 84, 214
thyroprotein, effect of, on rations for swine, 84
tryptophane, for growing pigs, 228
relationship of, to nicotinic acid, 228
urea, utilization of, by sheep, 26

vitamin A deficient beef bulls, 60
ascorbic acid in, 60
carotene in, 60
vitamin A, in blood of dairy calves, 70
vitamin A, in blood of swine, 222
vitamin B, in blood of swine, 222
vitamin B, in horses, 78
vitamin, B-complex as supplement to soybeans for pigs, 341
vitamin C, in blood of swine, 222
vitamin supplement for sows fed in drylot, 332

O

Ortho diluter—
results of, in inseminated dairy cows, 541

P

Pacific Northwest—
conditions for producing bacon-type hog, 511
climate, 511
feed, 511
Pantothenic acid—
deficiency of, in natural feedstuff diets of swine, 529
in studies with horses, 78
supplement to corn-soybean ration, 502
Paralysis—
experimentally induced in calves, 525
biotin in treatment of, 525
potassium in treatment of, 525
Parasites—
Haemonchus contortus, 466
hemopoietic dietary factors, effect of, on resistance of lambs to, 466
infection, effect on B-complex vitamins in blood of lambs, 520
effect on rumen of lambs, 520
in livestock, 517
Pastures—
alfalfa-bromegrass mixture, management of, 99
as supplement for feeding young pigs, 538
bromegrass mixed with alfalfa, management of, 99
chemical composition of, 536
digestibility of, 536
for swine, 537
management of alfalfa-bromegrass mixture, 99
Michigan's cow and calf feeder program, 536
for utilization of pasture, 536
for roughage, 536
nutritive value of forages, 373
of sheep's diet under range conditions, 170
palatability of, 536
relationship between chemical composition, digestibility and palatability of, 536
winter range, 529
supplementary feeding of individual sheep on, 529
Pernicious anemia—
liver extract, as growth stimulant in baby pigs, 528
Phosphate diluter—
results of, in inseminated dairy cows, 541
Phosphorus—
blood levels of, in range cattle, 263
supplements for fattening steers, 273
deflorinated superphosphate as, 273
Plant production—
relation of soil fertility to, 159
Plasma—
ascorbic acid levels in sheep, 191
chlorobutanol, effect of, on, 191
Poland China boars—
inbred with Landrace and purebred, 512
Potassium—
in treatment of experimentally induced paralysis in calves, 525
versus biotin, 525
Poultry—
rickets in, 534
vitamins D in treatment of, 534
thyroid functions in children, 546
Production—
animal, relation of soil fertility to, 159
blood phosphorus levels in range cattle for, 263
climate, relationship of, to animal, 391
hothouse lamb production, 513
preferred cuts of swine, yield of, 513
plant, relation of soil fertility to, 159
relation of body measurements to, 513
Protein—
amino acid, content of meat and meat products, 533
requirements, of swine, 530
of ruminants, 534
purified diets for study of, 534
amount of, effect on blood serum proteins, of pregnant ewes, 529
effect on offspring, 529
concentrate for pigs in drylot, 531

solvent extracted cottonseed meal as, 531
content of, in barley, 494
in oats, 494
in prairie hay, 110
in wheat, 494
cull peas as supplement for swine feeding, 177
dietary fat, effect of, on utilization of protein in rations of sheep, 475
distillers feeds, in rations of dairy calves, 434
iodized casein, influence of, on metabolism of milk cows, 291
kind of, effect on blood serum proteins of pregnant ewes, 529
effect on offspring, 529
lupine seed as protein supplement for beef steers, 526
lysine requirements of swine, 530
requirements of, for ruminants, 351
protein values of feeds, 351
significance of metabolic fecal nitrogen, 351
supplement to winter rations of beef steers, 430
tryptophane, relationship of, to nicotinic acid for growing pigs, 228
urea as extender of, in lambs, 35
wastage of, in cattle fed fibrous rations, 110
Pteroylglutamic acid deficiency—
synthetic diet for newborn pigs to produce, 486
Pyridoxine—
deficiency in baby pigs, 535

R

lactation performance of, on natural and purified rations, 531
effect of supplements on, 531
reproduction of, on natural and purified rations, 531
effect of supplements on, 531
thiouracil, effect of, on metabolism of, 521
vitamins D in treatment of rickets in, 534
Rickets, mammalian—
vitamin D, in treatment of, 534
cholesterilene sulfonic acid, 534
in chicks, 534
in rats, 534
Romney-Navajo, comparison with Corriedale×Navajo crosses, 455

S

Semen—
ascorbic acid, 60
failure to improve quality of, in vitamin-A deficient beef bulls, 60
bovine spermatozoa treated for control of trichomoniasis, 247
bull spermatozoa, preservation of, 447
hen egg yolk citrate as diluter, 447
turkey egg yolk citrate as diluter, 447
carotene, 60
effect of, on improving quality of, in vitamin-A deficient beef bulls, 60
chlorobutanol, effect of, on semen production in sheep, 191
freezing point depression of bull semen, 283
hyalurodinase, development of, in bull semen, 440
as factor of fertility, 440
association with spermatozoa, 440
effect of toluene on, 444
metabolic regulator in spermatozoa, 540, 541
of rams, effect of thyroprotein on, 191, 199, 449
motility scores, reliability in determining live normal sperm, 511
thyroprotein, effect of, on ram semen, 199
toluene, effect of, on development of hyalurodinase in bull semen, 444
Sex—
ratios among inbred, noninbred and line-cross pigs, 516
weaning weight of calves as related to, 514
Sexual activity—
ascorbic acid, 60
failure of, in vitamin-A deficient beef bulls, to improve, 60
carotene, 60
effect of, in vitamin-A deficient beef bulls, to improve, 60
Sheep—
bacteria in rumen of sheep, on summer rations, 525
in cobalt-deficient sheep, 526
on winter rations, 525
blood plasma vitamin C levels in newborn lambs, 527
administration of vitamin C, effect on, 527
carotene, absorption of, from gastrointestinal tract of, 539

chlorobutanol, effect of, on plasma ascorbic acid levels in, 191
effect of, on semen production in, 191
climatic stress, reactions of sheep to, 414
lamb production, 414
wool production, 414
cobalt, its function in sheep nutrition, 3
deficiency of, in sheep in New Hampshire, 16
effect in ration of, 523
Corriedale×Navajo, comparison with Romney×Navajo crosses, 455
diet, nutritive content of range forage in, 170
dietary fat, effect on utilization of rations by sheep, 475
environmental factors, effects of, on yearling Columbia rams, 181
on mature Rambouillet rams, 311
on yearling Rambouillet rams, 311
on yearling Targhee rams, 181
environments, two, reactions of Southdown sheep to, 41
grass tetany in ewes grazing winter oats, 535
Haemonchus contortus, in lambs, 466
effect of hemopoietic dietary factors, 466
infection, effect of, on B-complex vitamins in lamb's blood, 520
effect on rumen of lambs, 520
hothouse lamb production, 513
birth weights of, 513
daily gains in, 513
iodine deficiency in newborn, 298
Navajo×Corriedale, comparison with Navajo×Romney crosses, 455
Navajo ewes, 515
size of weaning lambs as permanent characteristic of, 515
parasitism in lambs, 466
Haemonchus contortus, 466
effect of hemopoietic dietary factors, 466
plasma, effect of chlorobutanol on, in sheep, 191
pregnant ewes, blood serum proteins of, 529
effect of amount of protein on, 529
of kind of protein, 529
offspring, blood serum proteins of, 529
effect of amount of protein on, 529
of kind of protein on, 529
ram semen, effect of thyroprotein on, 191, 199, 449
motility scores, reliability in determining live normal sperm, 511
production, effect of chlorobutanol on, in sheep, 191
Romney×Navajo, comparison with Corriedale×Navajo crosses, 455
soybean lecithin, effect on vitamin-A fed prepartum to ewe, 524
supplemental feeding of sheep on winter range, 529
thiouracil, effects of, on feeder lambs, 539
of similar compounds, 539
thyroprotein, effect of, on ram semen, 191, 199, 449
urea, utilization of, by sheep, 26
as extender of protein in lambs, 35
vitamin A, absorption of, from gastrointestinal tract of, 539
vitamin C for newborn lambs, 527
effect on blood plasma vitamin C levels, 527
weights of sheep, single and three-day, 50
winter range, supplementary feeding of individual sheep on, 529
Soil—
and alfalfa, as unidentified factor in young pig's appetite, 523
fertility, relation to animal production, 159
to plant production, 159
Solubles—
distillers, fed to pigs in drylot, 531
in rations of dairy calves, 434
dried fermentation, for sows during pregnancy and lactation, 332
fish, in drylot weanling pig rations, 535
whey, fermentation in drylot rations of weanling pigs, 535
use of dried whey with, 535
Soybean—
and corn, in ration of weanling pigs, 502
oil meal rations, for swine, 528
lactation studies of, 528
reproduction studies of, 528
supplemented, by, B-vitamins, 502
by known factors, 524
by unknown fators, 524
lecithin, effect on vitamin A fed prepartum to ewe and sow, 524
Steers—see cattle
Stilbestrol—
effect on growth and fattening of beef heifers, 523
Storage—
methods of protection of meat in freezer storage, 519

ultraviolet radiation of beef and pork for low temperature, 518
Sugar—
as production factor in hams, 517
Sweet potatoes, dehydrated—
as carbohydrate for fattening swine, 533
Swine—
alfalfa meal, dehydrated, in drylot weanling pig rations, 535
amino acid requirements of swine, 530
lysine, 530
bacon-type hog production in Pacific Northwest, 511
boars, comparisons of inbred Poland China, Landrace and purebred, 512
fertility of, when fed vitamin E deficient ration, 528
body measurements of, 513
relation to yield of 5 preferred cuts, 513
carbohydrate feed for fattening swine, 533
dehydrated sweet potatoes, 533
choline requirement of baby pig, 530
corn rations for swine, 527
by-products for swine rations, 527
manganese supplementation, effect on growth, 527
corn-soybean ration for weanling pigs, 502, 524
oil meal rations for swine, 528
lactation studies of, 528
reproduction studies of, 528
supplemented, by V-vitamins, 502
cottonseed meal, solvent extracted for pigs in drylot, 531
as protein concentrate, 531
cull peas as protein supplement for feeding of, 117
cystine as supplement to soybean diet for pigs, 341
DDT, in diet of pigs, 509
accumulation of, in tissues, 509
diet, effect of thiouracil on swine, 84
effect of, when given in addition to thyroprotein, 84
thyroprotein, effect of, 84
effect of, when given in addition to thiouracil, 84
dried fermentation solubles for sows during lactation, 332
during pregnancy, 332
feeding trials for swine, 320
female genital abnormalities in, 545
incidence, 545
fish solubles in drylot weanling pig rations, 535
hams, Southern style, 517
sugar, as production factor, 517
heterosis, study of, in swine, 515
hog, bacon-type, production in Pacific Northwest, 511
hog wallows, effect of, on gains in swine, 521
inbred lines of swine, selection in, 513
comparison of, based on performance of topcrosses, 515
inbred pigs, sex ratios among noninbred, linecross and, 516
iodine deficiency in, 298
Landrance boars, 512
comparisons with inbred Poland China and purebred, 512
linecross pigs, sex ration among inbred, noninbred and, 516
liver extract, antipernicious anemia, as growth stimulant in baby pigs, 528
news factors in, effect of, 528
low fertility of sows, 545
reproductive failures, 545
lysine requirements of swine, 530
manganese supplement, to corn rations for swine, 527
effect of, on growth of swine, 527
to corn by-products, 527
meat scraps in drylot weanling pig rations, 535
mortality of young pigs, 522
niacin levels, in blood of, 222
nicotinic acid, in blood of, 222
in growing pigs, 228
relationship of tryptophane to, 228
pantothenic acid deficiency in swine, 529
pasture for, 537
as supplement for feeding young pigs, 538
Poland China boars, 512
comparisons with inbred Landrace and purebred, 512
protein concentrate for pigs in drylot, 531
solvent extracted cottonseed meal as, 531
protein supplement for feeding of, 117
purebred boars, 512
comparisons with inbred Poland China and Landrace, 512
pyridoxine deficiency in baby pigs, 535
reproductive abnormalities, in sow, 540
histology of, 540
incidence, 540

reproductive failures in sows of low fertility, 545
sow's milk, composition, effect of lactation on, 521
effect of ration on, 521
sows, bred, efficiency of, when slaughtered, 92
sows, open, efficiency of when slaughtered, 92
soybean-corn, ration for weanling pigs, 502
oil meal rations, for swine, 528
lactation studies of, 528
reproduction studies of, 528
soybean lecithin, effect on vitamin A fed prepartum to sow, 524
soybeans, supplemented by cystine for pigs, 341
by B-complex vitamins, 341
by known factors, 524
by unknown factors, 524
synthetic diet for newborn pigs, 586
steroylglutamic acid deficiency, 486
temperature, adaptability of baby pigs to, 543
testicular development of, 512
thiouracil, effect of, in swine rations, 84, 215, 527
absorption of, in ruminants, 208
carcass composition of swine fed thiouracil, 533
effect of, on efficiency of gains in, 534
effect of, on rate of gains in, 534
effect of, on weight of thyroid gland, 214
effect of, when given in addition to thyroprotein in swine rations, 84
elimination of, in ruminants, 208
in non-ruminants, 208
nitrogen balances of swine fed thiouracil, 533
thyroid gland, effect of thiouracil on, 214
thyroid gland, effect of thiouracil on, 214
thyroprotein, effect of, in swine rations, 84, 527
effect of, on carcass quality in swine, 531
on fattening swine, 531
on growth of swine, 531
when given in addition to thiouracil, 84
topcross offspring of swine, 515
comparison of inbred lines of swine bred on, 515
vertebrae number in pigs, genetical researches on, 233
vitamin A in blood of, 222
vitamin B in blood of, 222
all B-vitamins, as supplements to corn-soybean ration, 502
vitamin B-complex for pigs, 341
as supplement to soybeans, 341
vitamin C in blood of, 222
vitamin supplement for pigs fed in drylot, 332
whey, dried, in drylot weanling pig rations, 535
whey fermentation solubles, in drylot weanling pig rations, 535

T

Targhee rams—
effects of environmental factors on yearling traits of, 181
Temperature—
adaptability of baby pigs to, 543
high ambient, reaction of dairy cattle to, 539
influence of body size on, 539
Testis—
development of, in swine, 512
inbreeding differences, 512
Testosterone—
effect of, on growth and fattening of beef heifers, 523
Tetany, grass—
in ewes grazing winter oats, 535
Thiouracil, in rations for swine, effect of, 84, 214, 527
carcass composition of swine fed, 533
effect of, on efficiency of gains in swine, 534
on rate of gains in swine, 534
on thyroid gland in swine, 214
feeding of, plus thyroidectomy to goats, 544
effect of, on carotene metabolism of, 544
nitrogen balances of swine fed, 533
when given in addition to thyroprotein, to swine, 84
Thyroid—
effect of, on gonads, to pregnant mares' serum, 542
effect, on growth and fattening of beef heifers, 523
function in chickens, 546
Thyroid gland—
effect of thiouracil on weight of, in swine, 214
removal of, plus thiouracil feeding to goats, 544
effect of carotene metabolism of, 544

Thyroprotein, in rations for swine, effect of, 84, 527
combined with estrogen for feeding, 541
effect on milk production, 541
effect of, on carcass quality in swine, 531
on carotene, in dairy calves' blood, 538
on fattening swine, 531
on growth to swine, 54
on vitamin A, in dairy calves' blood, 538
effect of, on feeding to dairy calves, 543
effect of, on ram semen, 191, 199, 449
when given in addition to thiouracil in rations for swine, 84
Tocopherol, alpha—
deficiency of, in boar rations, 528
effect on fertility of, 528
Toluene—
effect on hyalurodinase in bull semen, 444
Toxicity—
cobalt, in dairy calves, 239
Trichomoniasis, bovine—
effect of immune sera on semen for control of, 247
Tryptophane—
in growing pigs, 228
relationship of, to nicotinic acid, 228
Twins, identical cattle—
differentiation of fraternal and, 516
fraternal cattle, differentiation between, 516
similarities of, 511
blood composition, 511
growth, 511

U

Ultraviolet irradiation—
for low temperature storage of beef and pork, 518
Urea—
as extender of protein in lambs, 35
utilization of, by sheep, 26

V

Veneral disease—
in cattle, 247
Vertebrae—
number in pigs, genetical researches on, 233
Vitamins—
A, absorption of, from gastrointestinal tract of sheep, 539
A, deficient beef bulls, 60
ascorbic acid, failure of, to improve semen quality of, 60
sexual activity of, 60
carotene, effect on semen quality of, 60
effect on sexual activity of, 60
A, fed prepartum to ewe and sow, 524
effect of soybean lecithin on, 524
A, in blood of dairy calves, 70, 538
effect of thiouracil on, 538
of thyroprotein on, 538
relation of postnatal dietary changes to, 70
B, in horses, 78
B-complex, to supplement raw soybeans for pigs, 341
deficiency of, in natural feedstuff diets of swine, 529
deficiency of B_6, in baby pigs, 535
in blood of lambs, effect of parasitic infestion on, 520
in rations of dairy calves, 434
in studies with horses, 78
supplement, for sows fed in drylot, 332
to corn-soybean ration, 502
B-vitamin supplements to corn-soybean ration, 502
C, for newborn lambs, 527
effect of blood plasma vitamin C levels, 527
D, cholesterilene sulfonic acid, 534
in treatment of mammalian rickets, 534
E, deficiency of, in boar rations, 528
effect on fertility, 528
value of, in young pig's appetite, 523

W

Weight—
antipernicious anemia liver extract, as growth stimulant in baby pigs, 528
new factors in, effect of, 528
bonemeal, for fattening steers, 273
as supplement to winter rations of beef steers, 430
concentrate supplements for greenlot fattened steers, 537
cottonseed meal, solvent extracted, for pigs in drylot, 531
deflorinated superphosphate for fattening steers, 273
hog wallows, effect on gains of swine, 521
hothouse lamb production, birth weights of, 513
daily gains in, 513
lupine seed, for growing and fattening beef steers, 526
protein supplement for, 526
of sheep, single, 50
three-day, 50

protein supplement to winter rations for steer calves, 430
stilbestrol, effect on growth and fattening of beef heifers, 523
sweet potatoes, dehydrated, for fattening swine, 533
testosterone, effect on growth and fattening of beef heifers, 523
thiouracil, effect on fattening rations for Duroc swine, 527
effect of efficiency of gains in swine, 534
effect of rate of gains in swine, 534
thyroid gland of swine, effect of thiouracil on, 214
thyroid, effect on growth and fattening of beef heifers, 523
thyroprotein, effect on fattening rations for Duroc swine, 527
effect of, on growth of swine, 531
weaning lambs, size of, 515
as permanent characteristic of Navajo ewes, 515
weanling calves, initial and subsequent gains of, 279
relation of weaning weight, to age of dam, 514
to color, 514
to sex, 514
winter rations, effect of, on summer gains of steer calves, 536
winter supplementation, for beef steers, 430
effect on later gains of steer calves, 430
Whey—
dried, in drylot weanling pig rations, 535
fermentation solubles, in drylot weanling pig rations, 535
Wool—
productivity of lambs adapted to climatic stress, 414

AUTHOR INDEX FOR VOLUME 7

Acevedo, R., 214
Andrews, F. N., 298
Atkeson, F. W., 70

Bahler, T. L., 466
Baker, M. L., 279
Basu, P. T., 447
Bean, H. W., 50
Becker, D. E., 332, 501
Berge, S., 233
Berry, R. O., 447
Blaxter, K. L., 351
Blunn, C. T., 279
Bohstedt, G., 3, 222, 466
Bratton, R. W., 283
Bratzler, J. W., 475
Briggs, H. M., 35, 110
Brouse, E. M., 279
Burlison, W. L., 99

Cabell, C. A., 60
Caldwell, M. J., 70
Carroll, W. E., 332
Carter, R. H., 509
Childs, C. E., 198
Colby, R. N., 191
Comstock, R. E., 320, 341
Connell, W. E., 430
Cook, C. W., 170
Cunha, T. J., 117, 191

Dahlberg, F. I., 214
Dale, C. N., 228
Darlow, A. E., 35
Davis, R. E., 60
Doyle, L. P., 298
Dunn, K. M., 239

Eaton, O. N., 60, 449
Ellis, N. R., 228
Ely, R. E., 208, 239
Ensminger, M. E., 117

Fairbanks, B. W., 332
Flower, A. E., 198
Forbes, R. M., 373
Frank, A. H., 449
Fuellman, R. F., 99, 159

Gaines, W. L., 55
Gallup, W. D., 110
Garrigus, W. P., 373
Grandstaff, J. O., 455
Gregory, P. W., 426
Grummer, R. H., 222
Guilbert, H. R., 426

Ham, W. E., 198
Hamilton, T. S., 26, 159
Hankins, O. G., 509
Hansen, I. G., 291
Harper, C., 298
Harris, L. E., 170
Hart, N. K., 117
Hazel, L. N., 311, 181
Heemstra, L., 60
Heller, V. G., 35
Herrick, C. Q., 466
Hickman, C. E., 273
Hodgson, C. W., 273
Hostetler, E. H., 341
Hubanks, P. E., 509
Huffman, C. F., 239
Hughes, J. S., 70

James, M. F., 486, 501
James, W. H., 475
Johnson, B. C., 26, 486
Johnson, L. E., 92
Johnson, R. F., 273
Johnston, J. E., 440

Kammlade, W. G., 99, 159
Keener, H. A., 16
Knapp, B. Jr., 60
Knodt, C. B., 283, 434
Knox, J. H., 263
Krider, J. L., 332, 486, 501

Lee, D. H. K., 391
Lewis, J. M., 159
Lindley, C. E., 191
Lobay, W., 494

McElroy, L. W., 494
Madsen, L. L., 60
Mann, H. D., 509
Matsuchima, J., 127
Meek, D. C., 475
Miller, G. D., 251
Mitchell, H. H., 351
Mixner, J. B., 440
Monstgaard, J., 291
Morgan, B. B., 247
Morrow, K. S., 16

Olson, K. J., 208
Overman, O. R., 55

Parrish, D. B., 70
Pearson, H. F., 127
Pearson, P. B., 78, 214
Percival, G. P., 16
Peterson, W. J., 320, 341
Phillips, P. H., 3, 222, 466
Phillips, R. W., 41, 391
Pope, A. L., 3, 466
Powick, W. C., 228

Ray, S. N., 3
Reece, R. P., 84
Reineke, E. P., 208
Robinson, W. B., 26
Ruby, E. S., 279

Salisbury, G. W., 283
Schabinger, J. R., 434
Schmidt, H., 78
Schott, R. G., 449
Schweigert, B. S., 214
Sheath, D. M., 251
Shrewsbury, C. L., 298
Sidwell, G. M., 181, 311
Simmons, V. L., 449
Sinclair, R. D., 494
Skelley, W. C., 84
Smith, F. H., 341
Spencer, D. A., 41
Stewart, H. A., 320, 341
Stoddart, L. A., 170
Swift, R. W., 475

Terrill, C. E. 181, 311
Thorbeck, G., 291
Tillman, A. D., 475
Tom, R. C., 127, 430

Vander Noot, G. W., 84
Van Poucke, R. F., 501
Vestal, C. M., 298

Wagnon, K. A., 426
Wahid, A., 426
Warwick, E. J., 117, 191, 198
Washburn, L. E., 127
Watkins, W. E., 263
Webb, R. J., 159
Weir, W. C., 3, 466
Wheeler, S. S., 430
Whitehair, C. K., 222
Wiese, A. C., 273
Wise, G. H., 70
Wright, T., 92

Zeller, J. H., 509

V
4
C
V
4
X

V
4
N
C
4
X